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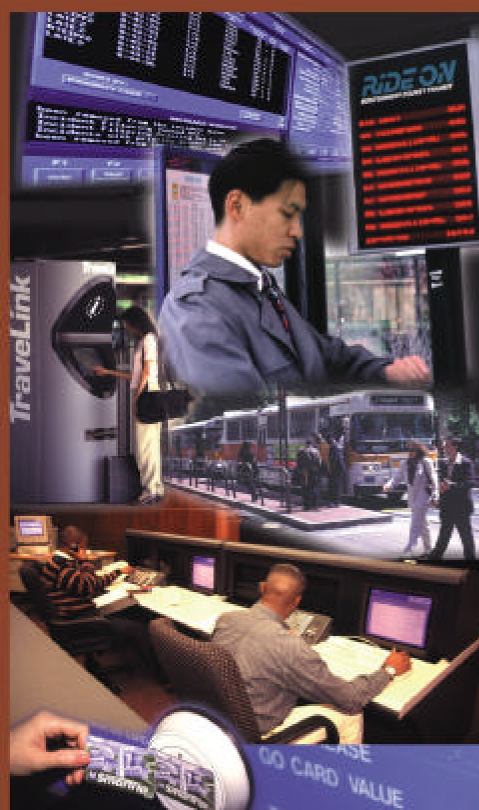
Benefits Assessment of Advanced Public Transportation System Technologies Update 2000



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This report was performed under the Federal Transit Administration's (FTA) Advanced Public Transportation Systems (APTS) Program. This program focuses on the development and demonstration of innovative advanced navigation, information and communication technologies that most benefit public transportation.

This report presents the results of an analysis conducted by the Volpe Center, for the FTA, to provide an "order-of-magnitude" estimate of the expected benefits to the transit industry with the application of APTS technologies. The study identified and quantified major benefits derived from current applications of APTS technologies and projected APTS benefits to a national level based on forecasts and reasonable assumptions on the future applications of APTS technologies within the transit industry.

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Benefits Assessment of Advanced Public Transportation System Technologies

Update 2000

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Advanced Public Transportation Systems Division
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November 2000

PREFACE

This research was conducted by the Office of System and Economic Assessment at the Volpe National Transportation Systems Center, Research and Special Programs Administration, U.S. Department of Transportation. This study was sponsored by the Federal Transit Administration's (FTA) Office of Mobility Innovation under its Advanced Public Transportation Systems (APTS) Program. As part of the U.S. DOT's initiative in Intelligent Transportation Systems (ITS), the APTS program focuses on the development, deployment and evaluation of advanced technologies to improve the safety, reliability, efficiency, and cost of public transportation services.

This study builds upon prior work, performed by the Volpe Center and other agencies, for the Federal Transit Administration under the APTS Program. Available studies and surveys of APTS technology applications were reviewed to identify the major deployments and benefits derived. Based on these reviews, this study quantified major benefits derived from current applications of APTS technologies and projected APTS benefits to a national level based on forecasts and reasonable assumptions on the future applications of APTS technologies.

The author would like to thank Mr. Walt Kulyk, Director of the FTA's Office of Mobility Innovation, and Messrs. Ronald Boenau, W. Raymond Keng, and Brian Cronin of the same organization for their guidance, direction, and valuable comments in the preparation of this report.

METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in)	=	2.5 centimeters (cm)
1 foot (ft)	=	30 centimeters (cm)
1 yard (yd)	=	0.9 meter (m)
1 mile (mi)	=	1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq. in, in^2)	=	6.5 square centimeters (cm^2)
1 square foot (sq. ft, ft^2)	=	0.09 square meter (m^2)
1 square yard (sq. yd, yd^2)	=	0.8 square meter (m^2)
1 square mile (sq. mi., mi^2)	=	2.6 square kilometers (km^2)
1 acre = 0.4 hectare (he)	=	4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz)	=	28 grams (gm)
1 pound (lb.)	=	0.45 kilogram (kg)
1 short ton = 2,000 pounds (lb.)	=	0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp)	=	5 milliliters (ml)
1 tablespoon (tbsp)	=	15 milliliters (ml)
1 fluid ounce (fl oz)	=	30 milliliters (ml)
1 cup (c)	=	0.24 liter (l)
1 pint (pt)	=	0.47 liter (l)
1 quart (qt)	=	0.96 liter (l)
1 gallon (gal)	=	3.8 liters (l)
1 cubic foot (cu ft, ft^3)	=	0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3)	=	0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x-32)(5/9)] F	=	Y C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm)	=	0.04 inch (in)
1 centimeter (cm)	=	0.4 inch (in)
1 meter (m)	=	3.3 feet (ft)
1 meter (m)	=	1.1 yards (yd)
1 kilometer (km)	=	0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2)	=	0.16 square inch (sq. in, in^2)
1 square meter (m^2)	=	1.2 square yards (sq. yd, yd^2)
1 square kilometer (km^2)	=	0.4 square mile (sq. mi., mi^2)
10,000 square meters (m^2)	=	1 hectare (ha) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gm)	=	0.036 ounce (oz)
1 kilogram (kg)	=	2.2 pounds (lb.)
1 tonne (t)	=	1,000 kilograms (kg)
	=	1.1 short tons

VOLUME (APPROXIMATE)

1 milliliter (ml)	=	0.03 fluid ounce (fl oz)
1 liter (l)	=	2.1 pints (pt)
1 liter (l)	=	1.06 quarts (qt)
1 liter (l)	=	0.26 gallon (gal)
1 cubic meter (m^3)	=	36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3)	=	1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

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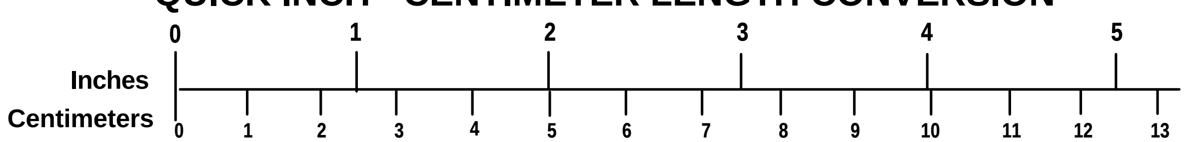
QUICK INCH - CENTIMETER LENGTH CONVERSION



QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSION

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50 SD Catalog No. C13 10286

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Executive Summary

Background

The Federal Transit Administration (FTA) created the Advanced Public Transportation Systems (APTS) Program, as part of the U. S. Department of Transportation's initiative in Intelligent Transportation Systems (ITS), to foster the development and implementation of advanced technologies in the transit industry. Through the APTS Program, the Federal Transit Administration is making substantial investments in the deployment and evaluation of advanced technologies to improve the safety, reliability, efficiency, and cost of public transportation services.

The FTA's APTS Program involves the application and integration of existing and emerging technologies in the following major functional areas:

- *Fleet Management Systems (FMS)* involve the integration of fleet based communication, automatic passenger counting, vehicle monitoring/location, and vehicle control technologies to improve the overall planning, scheduling, and operations of transit systems.
- *Operational Software and Computer Aided Dispatching Systems (OS/CAD)* are automated systems designed to improve the effectiveness of transit scheduling, dispatching, service planning and operations. When linked with automated vehicle monitoring and control systems, transit operational software and computer-aided dispatch systems provide real-time dispatching of vehicle fleets, faster responses to service disruptions, and improved coordination of transit services.
- *Advanced Traveler Information Systems (ATIS)* include a broad range of advanced computer and communication technologies designed to provide transit riders pre-trip and real-time information to make better informed decisions regarding their mode of travel, planned routes, and travel times. ATIS systems include in-vehicle annunciators and displays, terminal or wayside based information centers, telephone information systems, and systems that provide information via cable TV, interactive TV, and the internet.
- *Electronic Fare Payment Systems (EFP)* are advanced fare collection and fare media technologies, designed to make fare payment more convenient for transit users and fare collection more efficient and more flexible for the transit provider. These systems include fare media, ranging from magnetic strip to smart cards, and their associated fare collection and processing systems.
- *Intelligent Vehicle Initiative (IVI)* involves the development, evaluation and deployment of advanced vehicle technologies, vehicle collision warning, and driver information systems to improve the safety and efficiency of transit operations.

Study Objectives

This report documents the results of an analysis conducted by the Volpe Center, for the Federal Transit Administration, to provide an 'order-of-magnitude' estimate of the expected benefits to the transit industry with the application of Advanced Public Transportation System technologies in the United States. Specifically, the following objectives were established for this study:

- Identify and quantify the major benefits derived from current applications of APTS technologies within the transit industry.
- Project current APTS benefits to a national level based on forecasts and reasonable assumptions on the potential future applications of such technologies within the transit industry.

Study Scope and Approach

The study addressed five major APTS program areas, shown in Table ES-1, with applications in the fixed-route bus, demand responsive transit, and rail transit systems.

Table ES-1. APTS Program Applications Considered

APTS Program Area	Fixed-Route Bus	Demand Responsive Transit	Commuter Rail	Heavy Rail	Light Rail
Fleet Management Systems (FMS)	✓	✓	✓	✓	✓
Operational Software/Computer Aided Dispatching Systems (OS/CAD)	✓	✓	✓	✓	✓
Advanced Traveler Information Systems (ATIS)	✓	✓	✓	✓	✓
Electronic Fare Payment Systems (EFP)	✓	✓	✓	✓	✓
Transit Intelligent Vehicle Initiative (IVI)	✓				

This study built upon prior work, performed by the Volpe Center and other agencies, for the Federal Transit Administration under the APTS Program. Available studies and surveys of APTS technology applications were reviewed to identify the major deployments and benefits derived. Using the cited benefit areas, estimating relationships were developed to quantify APTS benefits based on available transit data. For this analysis, the most recent data on transit system characteristics, reported under the FTA's 1997 National Transit Database (NTDB) program, were used. APTS benefits were projected to a national level based on a projection of future transit deployments[1] of APTS technologies.

A ten-year period (2000-2009) was chosen as the timeframe of the analysis, with current and projected APTS applications being characterized as falling within one of the three following timeframes:

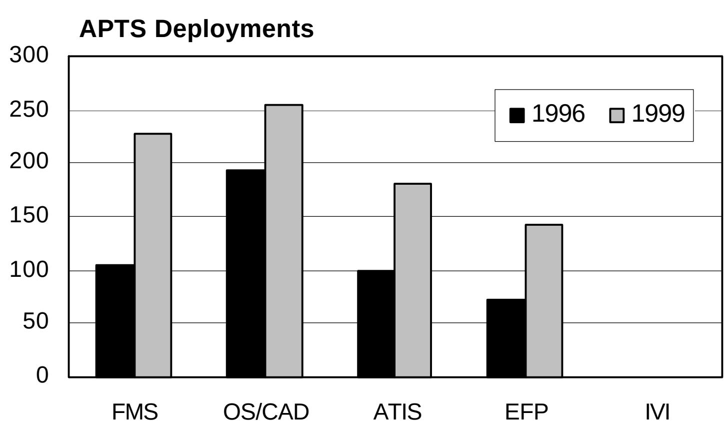
[1] The term 'deployment' used throughout this report refers to the application of an APTS system technology by a transit agency for a specific mode of operation (fixed-route bus, demand responsive transit, heavy rail, etc.). A transit agency, that has an application of a fleet management system for its fixed-route bus and demand responsive transit operations, is considered as having two APTS fleet management system deployments.

- *Operational APTS Systems* - representing currently deployed APTS technologies within the transit industry. The benefits of these deployments are accrued over the entire ten years of the analysis period.
- *APTS Systems Under Implementation* - representing APTS applications that are expected to be deployed in the transit industry over the next two to three years. The benefits of these applications are accrued over a seven year period (2003-2009).
- *Planned APTS Systems* - representing those APTS applications that are expected to be deployed over the next four to five years. The benefits of these deployments are accrued over a five year period (2005-2009) under the analysis.

The study projected a range of estimated program benefits (minimum, most likely, and maximum), based on assumed probability distributions of key model input variables. These estimates were developed because of the nature and uncertainties in the reported benefits from current APTS applications within the transit industry. All benefits are calculated in current year (2000) constant dollars and discounted to present-value year 2000 dollars using the OMB recommended discount rate of 7%. Analysis results are presented as year 2000 constant and discounted, present-value dollars.

Summary of Results

Over the past five years, there has been a significant increase in the number of deployments of APTS system technologies within the transit industry (see Figure ES-1). Since 1996, the number of deployments of APTS technologies have increased by over 70%, with the largest increases seen in the deployments of fleet management systems, electronic fare payment systems, and advanced traveler information systems.



Number of APTS Deployments

	1996	1999	% increase
FMS	105	228	117%
OS/CAD	194	255	31%
ATIS	99	180	82%
EFP	72	142	97%
IVI	0	0	0%
Total	470	805	71%

Figure ES-1. Growth in APTS Deployments

Today, APTS technologies are deployed (or are being planned for deployment) within 192 fixed-route bus systems, 153 demand responsive transit systems, 11 heavy rail, 12 light rail, and 13 commuter rail systems. Transit IVI technologies are currently being researched and initial in-vehicle collision warning systems are being developed, tested and evaluated. An initial deployment of a Transit IVI side collision warning system is planned to be evaluated on a fleet of 100 buses at the Port Authority of Allegheny County (PAT) Transit Authority (Pittsburgh, PA) by FY2001. Transit IVI rear impact and frontal collision warning systems will be developed, tested and evaluated, respectively, at the Ann Arbor Transportation Authority (AATA) in Ann Arbor, MI and the San Mateo County Transit District (SamTrans) in San Carlos, CA. This analysis assumed that APTS IVI technologies would be deployed on fixed-route bus systems under a phased program beginning in Year 2003.

Because of the availability of transit characteristic data, reported under the 1997 National Transit Database (NTDB), this analysis considered a total of 683 deployments of APTS technologies for this analysis. Presented in Table ES-2 is a summary count of deployments considered, by APTS technology area and deployment status.

Table ES-2. APTS Technology Deployments Considered in the Analysis

APTS Program Area	Operational	Under Implementation	Planned	Total
Fleet Management Systems	66	31	94	191
Operational Software/Computer Aided Dispatching Systems	126	25	72	223
Advanced Traveler Information Systems	84	24	43	151
Electronic Fare Payment Systems	43	7	68	118
Transit Intelligent Vehicle Initiative	Planned deployment on fixed route bus systems beginning in Year 2003			
Total	319	87	277	683

Table ES-3 summarizes the major program benefits that have been identified for each of the APTS system technologies.

Table ES-3. Summary of APTS Program Benefits

Fleet Management Systems	• Increased transit safety and security • Improved operating efficiency • Improved transit service and schedule adherence • Improved transit information
Operational Software and Computer Aided Dispatching Systems	• Increased efficiency in transit operations • Improved transit service and customer convenience • Increased compliance with transit Americans with Disabilities Act (ADA) requirements
Electronic Fare Payment Systems	• Improved security of transit revenues • Increased customer convenience • Expanded base for transit revenue • Reduced fare collection and processing costs • Expanded and more flexible fare structures
Advanced Traveler Information Systems	• Increased transit ridership and revenues • Improved transit service and visibility within the community • Increased customer convenience • Enhanced compliance with Americans with Disabilities Act
Transit Intelligent Vehicle Initiative	• Increased safety of transit passengers • Reduced costs of transit vehicle maintenance and repairs • Enhanced compliance with Americans with Disabilities Act

This analysis found that the projected benefits for all APTS technology deployments, that are currently operational, under implementation, or planned for deployment over the next ten years, would range from as low as $3.9 billion to as high as $9.6 billion, in discounted, present value dollars. The most likely estimate of the total APTS Program benefits (over the ten year period 2000-2009) is $6.7 billion, in discounted, present value dollars. Figure ES-2 presents the minimum, most likely and maximum estimates of total program benefits for each of the APTS technology areas.

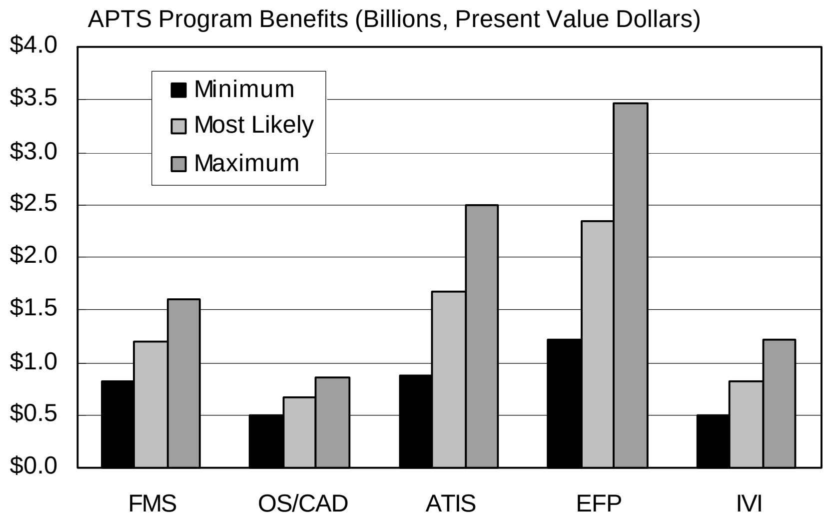


Figure ES-2. Total APTS Program Benefits

For the study's most likely estimate, the deployments of APTS electronic fare payment systems represent nearly 35% of the total projected benefits, while deployments of APTS advanced traveler information systems account for 25% of the total projected benefits. APTS fleet management systems and the planned deployment of APTS IVI technologies represent 18% and 12%, respectively, of the total projected APTS Program benefits. The deployment of APTS operational software and computer-aided transit dispatching systems represent the remaining 10% of the projected APTS Program benefits.

Table ES-4 summarizes the total projected minimum, most likely, and maximum program benefits of each APTS technology for the ten year period 2000-2009. These benefits are presented in millions of discounted, present value dollars. The table also identifies, for each of the APTS technology areas, the distribution of total program benefits that are accrued from program deployments that are currently operational, under implementation or planned for implementation.

Table ES-4. APTS Total Program Benefits

Minimum Estimate	Discounted Present Value Dollars (Millions)			
	Operational	Implementation	Planned	Total
Fleet Management Systems	$557.2	$153.9	$99.7	$810.8
OS / CAD Systems	$360.5	$52.8	$88.9	$502.3
Advanced Traveler Information Systems	$634.7	$163.7	$72.5	$870.8
Electronic Fare Payment Systems	$1,123.1	$4.0	$91.6	$1,218.7
Transit Intelligent Vehicle Initiative			$498.0	$498.0
Total	$2,675.6	$374.3	$850.7	$3,900.6
Most Likely Estimate	Discounted Present Value Dollars (Millions)			
	Operational	Implementation	Planned	Total
Fleet Management Systems	$821.5	$226.1	$146.9	$1,194.5
OS / CAD Systems	$478.1	$71.9	$125.4	$675.5
Advanced Traveler Information Systems	$1,223.0	$317.7	$141.8	$1,682.5
Electronic Fare Payment Systems	$2,150.3	$7.7	$178.2	$2,336.1
Transit Intelligent Vehicle Initiative			$819.6	$819.6
Total	$4,672.9	$623.4	$1,411.9	$6,708.2
Maximum Estimate	Discounted Present Value Dollars (Millions)			
	Operational	Implementation	Planned	Total
Fleet Management Systems	$1,089.5	$301.9	$200.5	$1,591.9
OS / CAD Systems	$594.3	$92.8	$166.3	$853.3
Advanced Traveler Information Systems	$1,813.0	$469.2	$210.0	$2,492.2
Electronic Fare Payment Systems	$3,182.0	$11.5	$271.4	$3,464.9
Transit Intelligent Vehicle Initiative			$1,225.6	$1,225.6
Total	$6,678.8	$875.4	$2073.8	$9,628.0

List of Acronyms

AATA	Ann Arbor Transportation Authority
ADA	American with Disabilities Act
APC	Automatic Passenger Counters
APTS	Advanced Public Transportation Systems
ATC	Automatic Train Control
ATIS	Advanced Traveler Information Systems
AVI	Automatic Vehicle Identification
AVL	Automatic Vehicle Location
AVM	Automatic Vehicle Monitoring
BART	Bay Area Rapid Transit District (Oakland, California)
BRT	Bus Rapid Transit
CAD	Computer-Aided Dispatch
CASM	Computer Aided Support Management
CPSFIP	Central Puget Sound Regional Fare Integration Project
CTA	Chicago Transit Authority
DGPS	Differential Global Positioning System
DOT	Department of Transportation
DRT	Demand Responsive Transit
DPW	Department of Public Works
DVI	Driver Vehicle Interface
EFP	Electronic Fare Payment
FARS	NHTSA’s Fatal Accident Reporting System
FCWS	Frontal Collision Warning System
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
GBRPS	Ground-Based Radio Positioning And Paging Systems
GES	NHTSA’s General Estimates System
GIS	Geographic Information Systems
GPS	Global Positioning System
ICAS	Intersection Collision Avoidance System
ITS	Intelligent Transportation Systems
IVI	Intelligent Vehicle Initiative
JPO	Joint Project Office
KCATA	Kansas City Area Transportation Authority
LACMTA	Los Angeles County Metropolitan Transit Authority
MARTA	Metropolitan Atlanta Rapid Transit Authority
MBTA	Massachusetts Bay Transportation Authority

List of Acronyms (cont.)

MDT	Mobile Data Terminal
MMDI	Metropolitan Model Development Initiative
MTA	Mass Transit Administration (Maryland MTA)
MTA	Metropolitan Transportation Authority (New York City)
MTS	Milwaukee Transit System
Muni	San Francisco Municipal Railway (Muni)
NAS	National Academy of Science
NCTRP	National Cooperative Transit Research Program
NHTSA	National Highway Traffic Safety Administration
NTDB	National Transit Database
NJT	New Jersey Transit
NYCTA	New York City Transit Authority
OMB	Office of Management and Budget
OS	Operational Software
OST	Office of the Secretary
OS/CAD	Operational Software/Computer-Aided Dispatching
PAT	Port Authority of Allegheny County
RF	Radio Frequency
RICWS	Rear Impact Collision Warning System
RTA	Chicago Regional Transportation Authority
RTD	Denver Regional Transportation District
SamTrans	San Mateo County Transit District
SAMIS	Safety Management Information Statistics
SCWS	Side Collision Warning System
SBIR	Small Business Innovative Research
SCADA	Supervisory Control and Data Acquisition System
SOA	State-of-Art
TRB	Transportation Research Board
Tri-Met	Tri-County Metropolitan Transportation District (Portland, OR)
VLU	Vehicle Logic Unit
VRM	Vehicle Revenue Miles
VSM	Vehicle Service Miles
Volpe Center	Volpe National Transportation Systems Center
WMATA	Washington Metropolitan Area Transit Authority
WSTA	Winston-Salem Transit Authority

Section 1
Introduction

The Federal Transit Administration (FTA) created the Advanced Public Transportation Systems (APTS) Program, as part of the U. S. Department of Transportation's initiative in Intelligent Transportation Systems (ITS), to foster the development and implementation of advanced technologies in the transit industry. Through the APTS Program, the Federal Transit Administration is making substantial investments in the deployment and evaluation of advanced technologies to improve the safety, reliability, efficiency, and cost of public transportation services.

The FTA's APTS Program involves the application and integration of existing and emerging technologies in the areas of communications, navigation, information processing, and control systems to improve the effectiveness of transit operations. The APTS Program is structured along the following major functional areas:

- *Fleet Management Systems (FMS)* involve the integration of fleet based communication, automatic passenger counting, vehicle monitoring/location, and vehicle control technologies to improve the overall planning, scheduling, and operations of transit systems.
- *Operational Software and Computer Aided Dispatching Systems (OS/CAD)* are automated systems designed to improve the effectiveness of transit scheduling, dispatching, service planning and operations. When linked with automated vehicle monitoring and control systems, transit operational software and computer-aided dispatch systems provide real-time dispatching of vehicle fleets, faster responses to service disruptions, and improved coordination of transit services.
- *Advanced Traveler Information Systems (ATIS)* include a broad range of advanced computer and communication technologies designed to provide transit riders pre-trip and real-time information to make better informed decisions regarding their mode of travel, planned routes, and travel times. ATIS systems include in-vehicle annunciators and displays, terminal or wayside based information centers, telephone information systems, and systems that provide information via cable TV, interactive TV, and the internet.
- *Electronic Fare Payment Systems (EFP)* are advanced fare collection and fare media technologies, designed to make fare payment more convenient for transit users and fare collection more efficient and more flexible for the transit provider. These systems include fare media, ranging from magnetic strip to smart cards, and their associated fare collection and processing systems.
- *Intelligent Vehicle Initiative (IVI)* involves the development, evaluation and deployment of advanced vehicle technologies, vehicle collision warning, and driver information systems to improve the safety and efficiency of transit operations.

Section 2
Study Objective

This report documents the results of an analysis conducted by the Volpe Center, for the Federal Transit Administration, to provide an 'order-of-magnitude' estimate of the expected benefits to the transit industry with the application of Advanced Public Transportation System technologies. Specifically, the following objectives were established for this study:

- Identify and quantify the major benefits derived from current applications of APTS technologies within the transit industry.
- Project current APTS benefits to a national level based on forecasts and reasonable assumptions on the potential future applications of such technologies within the transit industry.

Section 3
Analysis Approach, Data, and Assumptions

The study addressed five major APTS program areas, shown in Table 3-1, with applications in the fixed-route bus, demand responsive transit, and rail transit operations.

Table 3-1. APTS Program Applications Considered

APTS Program Area	Fixed-Route Bus	Demand Responsive Transit	Commuter Rail	Heavy Rail	Light Rail
Transit Fleet Management Systems	✓	✓	✓	✓	✓
Operational Software/Computer Aided Dispatching Systems	✓	✓	✓	✓	✓
Advanced Traveler Information Systems	✓	✓	✓	✓	✓
Electronic Fare Payment Systems	✓	✓	✓	✓	✓
Transit Intelligent Vehicle Initiative	✓				

This study built upon prior work, performed by the Volpe Center and other agencies, for the Federal Transit Administration under the APTS Program. The overall study framework, depicted in Figure 3-1, consisted of the following steps:

- Available studies and surveys of APTS technology applications were reviewed to identify the major deployments and benefits derived.
- In those areas where benefits were identified, cited benefits were correlated to the type and class of APTS application.

- Using the cited benefit areas, estimating relationships were developed to quantify APTS benefits based on available transit data. For this analysis, the most recent data on transit system characteristics, reported under the FTA's 1997 National Transit Database (NTDB) program [Ref.1], was used.
- APTS benefits were projected to a national level based on a projection of future transit deployments of APTS technologies.
- Because of the nature of the reported benefits from current applications and the uncertainty in the quantification of these benefits, a range of estimates (minimum, most likely, and maximum) was established on the projected level of benefits. This analysis utilized a simulation process, termed @ Risk™, along with a Microsoft-Excel spreadsheet model to compute the projected level of benefits based on probability distributions on key model input variables. Appendix A presents a brief description of the simulation process used in this analysis, along with a description of the probability distributions used on each of eight key model input variables.

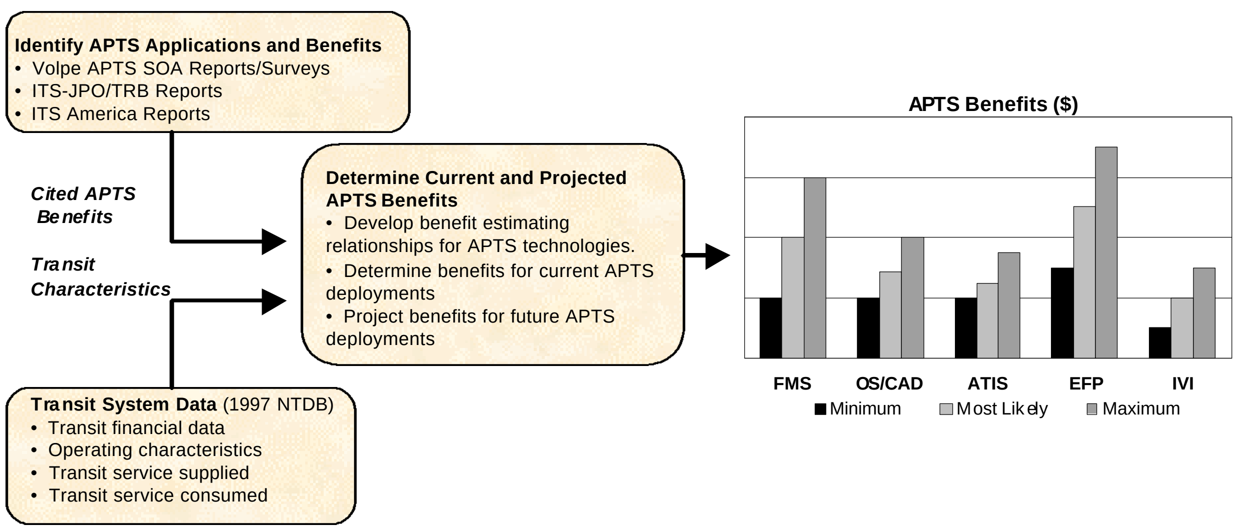


Figure 3-1. Analysis Framework

The study was structured to address the current and projected deployments of APTS technologies, based on recent surveys and analyses [Refs. 2, 3, 4, 5] conducted by the Volpe Center. A ten-year period (2000-2009) was chosen as the overall timeframe of the analysis, with current and projected APTS applications being characterized as falling within one of the three following timeframes (as shown in Figure 3-2):

- *Operational APTS Systems* - representing currently deployed APTS technologies within the transit industry. The benefits are accrued over the entire ten years of the analysis period.
- *APTS Systems Under Implementation* - representing APTS applications that are expected to be deployed in the transit industry over the next two to three years. The benefits of these applications are accrued over a seven year period (2003-2009).

- *Planned APTS Systems* - representing those APTS applications that are expected to be deployed over the next four to five years. The benefits are accrued over a five year period (2005-2009) under the analysis.

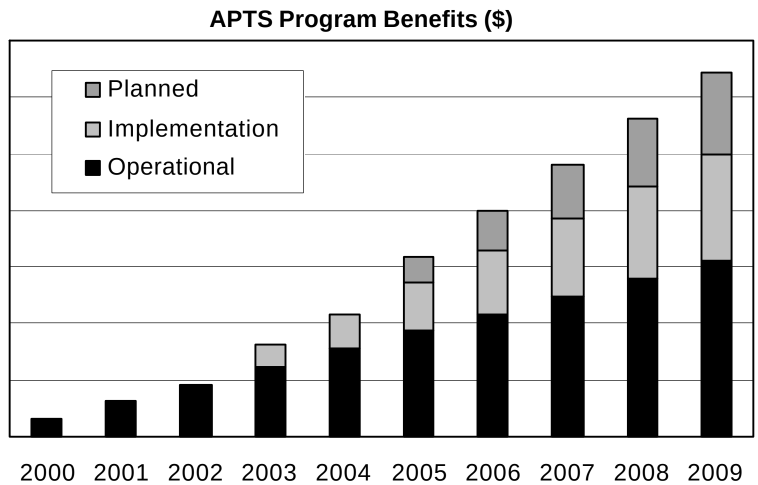


Figure 3-2. Analysis Timeframe

The study considered the deployment of APTS technologies over all transit systems[2] reporting under the FTA's 1997 National Transit Database (NTDB) system. Table 3-2 presents the total count of transit agencies (by transit mode) and the total size of the vehicle fleet along with the number of transit systems (and their respective modal fleet sizes) that have some form of APTS technology deployment. As shown, the deployment of APTS technologies within the transit industry is widespread and significant representing 40%-80% of the number of transit agencies and 60%-95% of the transit modal vehicle fleet.

Table 3-2. APTS Technology Deployments within the Transit Industry

	All Transit Systems in 1997 NTDB		Transit Systems with APTS Deployments		% of Transit System Totals that have APTS Technologies	
Mode	# Transit Systems	# Vehicles (total fleet)	# Transit Systems	# Vehicles (total fleet)	% of Number of Systems	% of Modal Fleet Size
Fixed Route Bus	401	54,152	192	38,330	47.9%	70.8%
Demand Responsive Transit	389	19,785	153	11,252	39.3%	56.9%
Heavy Rail	14	10,228	11	9,634	78.6%	94.2%
Light Rail	20	1,062	12	863	60.0%	81.3%
Commuter Rail	16	5,425	13	5,031	81.3%	92.7%
Total Bus	790	73,937	345	49,582	43.7%	67.1%
Total Rail	50	16,715	36	15,528	72.0%	92.9%
Grand Total	840	90,652	381	65,110	45.4%	71.8%

[2] All transit systems reporting under the Federal Transit Administration's National Transit Database for 1997 were considered in the analysis. The table reflects the total count of transit systems and the total size of their modal vehicle fleets as reported in the 1997 NTDB. Ferry boat and automated guideway transit systems were not considered in the analysis.

Appendix B presents an identification of all the transit systems considered in the analysis. The appendix is organized by class of APTS deployment[3] and whether these deployments are operational, under implementation or planned. The most recent survey[4] of APTS deployments, that was conducted by the Volpe Center [Ref. 5], and information from ITS deployment surveys conducted for the U.S. Department of Transportation's Intelligent Transportation System Joint Program Office (ITS-JPO) [Ref. 6], served as the source on current and projected APTS technology deployments.

For each of the APTS deployment systems, data representing the current (1997) financial, operating and performance characteristics were established based on the information that these systems reported within the 1997 NTDB. A summary of the NTDB information, used in this analysis, is presented within Appendix C of this report.

The primary assumptions used in this analysis were:

- The analysis considered a ten-year time horizon (2000-2009) for the deployment of APTS technologies.
- All benefits are calculated in current year (2000) constant dollars and discounted to present-value year 2000 dollars. Analysis results are presented as year 2000 constant and discounted, present-value dollars.
- The Office of Management and Budget (OMB) guidelines[5] and recommended discount rate of 7.0% were used in the calculation of all present-value dollar benefits.
- Transit ridership (as measured by the reported number of unlinked passenger trips) was assumed to have increased at a rate of 1% per year for the period 1997-2000 and then to increase at an average annual rate ranging from 1%-3% for the period 2000-2009. The analysis used a probability distribution function to model the projected annual increase in transit ridership for the period 2000-2009. The analysis used assumed values of: 1% (minimum), 2% (most likely) and 3% (maximum) for this input variable. Recent national trends [Ref.1] indicate that overall transit ridership increased at an average annual rate of 1.8% over the four year period 1993-1997. For the 1997 reporting year, transit ridership (unlinked passenger trips of all modes) increased 5.2%, over the number of transit trips taken in1996, to a level of 7,954 million passenger trips.
- Transit operating costs were assumed to increase at an average annual rate of 3%, for the period 1997-2000, and at an annual rate ranging from 2%-5% over the next ten years (2000-2009). The analysis used a probability distribution function to model this input variable with assumed values of: 2% (minimum), 3% (most likely) and 5% (maximum). This reflects the national trends [Ref.1] in transit operating costs which

3 For this analysis, APTS system deployments were organized in the following classes of technology deployments: fleet management systems, operational software and computer aided dispatching systems, advanced traveler information systems, electronic fare payment systems, and IVI.

4 The survey entitled: 'Advanced Public Transportation Systems Deployment in the United States', Volpe Center, January 1999 surveyed a total of 551 transit agencies covering the time period July,1998 to December,1998. The results of this survey was cross-checked with survey results conducted in FY1996 and FY1997 for the U.S. DOT's ITS Joint Program Office on ITS-Transit applications.

5 'Guidelines and Discount Rates for Benefit-Cost Analyses of Federal Programs;' Office of Management and Budget: Circular No. A-94 (revised), Transmittal Memorandum No. 64; October 29, 1992.

show a total increase of 9.6% in transit operating costs for all modes over the four-year period (1993-1997). This represents an average annual increase of 2.4% in all transit operating costs over this period.

- Transit service supplied, as measured by scheduled vehicle revenue miles, was assumed to increase at a rate of 2% per year for the period 1997-2000, and then at an average annual rate ranging from 2% to 5% for the period 2000-2009. The analysis used a probability distribution function to model this input variable with assumed values of: 2% (minimum), 3% (most likely) and 5% (maximum). For the period 1993-1997, transit revenue miles (across all modes) increased by 10% (or at an average annual rate of 2.5%) to 2,853 million vehicle revenue miles in 1997 [Ref.1]. Transit vehicle revenue miles for the last reporting year (1996-1997) showed an increase of 3.7%.

- Transit fares, as measured in dollars per unlinked passenger trip, were assumed to increase at an average annual rate ranging from 1% to 3% over the period 2000-2009. The analysis used a probability distribution function to model this input variable with assumed values of: 1% (minimum), 2% (most likely) and 3% (maximum) over a base fare of $0.90 per passenger trip in the year 2000. The most recent data [Ref.1] shows that transit fares over the four year period (1993-1997) have increased by 9.9% from $0.81 per passenger trip in 1993 to $0.89 per passenger trip in 1997. This represents an average annual increase of nearly 2.5% over this period.

A summary of the primary input variables and assumed values used in this analysis is presented in Table 3-3.

Table 3-3. Summary of Analysis Input Variables and Assumptions

Input Variable	% annual increase (1997-2000)	% annual increase (2000-2009)		
		Minimum	Most Likely	Maximum
Transit ridership	1%	1%	2%	3%
Transit operating costs	3%	2%	3%	5%
Transit service (VRMs)	2%	2%	3%	5%
Transit fares	$0.90/passenger trip in 2000	1%	2%	3%
OMB discount rate 7%				

Section 4

Fleet Management Systems

Fleet management systems refer to a broad range of APTS technologies designed to improve the planning, scheduling of transit services and the operations of transit vehicle fleets. These technologies include:

- Advanced vehicle and control center communication systems
- Automatic vehicle location and monitoring (AVL/AVM) systems
- Automated passenger counters (APC)
- Centralized operations control and dispatch centers.

Automatic vehicle location and monitoring systems are a complement of technologies that track and report vehicle locations in an accurate and timely manner. At a minimum, each automatic vehicle location deployment includes a specific location technology and a method of transmitting the location data from the bus to a central dispatch center. Many of the more recent transit applications of AVL/AVM systems have integrated the automated vehicle location component with other system components (such as communications, geographic information systems, analysis software, and dispatch/control systems) to expand the use of AVL for more efficient fleet operations, route/service data collection, security, and traveler information services. Some of the expanded applications of AVL/AVM systems with other APTS technologies include:

- Schedule adherence monitoring
- Transit security and silent alarm
- Automated passenger counters
- Automated traveler information services
- Computer-aided dispatch and control
- Vehicle component monitoring (engine temperature, oil pressure conditions)
- Traffic signal preferential control.

A recent synthesis [Ref.7] of AVL system applications, within the bus transit industry, characterizes AVL systems into three functional units: navigation, communications and interface integration. The navigation and communication components are composed of on-board and system infrastructure technologies. Most AVL navigation systems use radio frequency (RF) for communications. These units, located on-board the vehicle, transmit and receive signals from various infrastructure devices such as wayside beacons, radio towers, and/or satellites. In turn, the communications component transmits signals from the on-board equipment to a central dispatch center through a network of RF relay stations and towers. The performance of these systems is driven by the integration of the AVL technology with a vehicle monitoring capability

(AVM) and other related automation systems. The central control system is the AVM component that monitors vehicle operations in adherence to schedules and the status of on-board equipment (silent alarm, engine conditions). The centralized dispatch and control center integrates the information collected and provides the interface for the dissemination of information on the status of operations to various traveler information services and/or traffic control centers.

The primary types of navigation technologies in use for AVL are:

- Signpost/odometer systems which utilize a network of radio beacons along the bus routes. Signpost systems can operate in either one of two ways. One method is to have the signpost transmit a low-power signal that is received by an on-board receiver and is used by the vehicle to transmit its position, along with distance (odometer) and other sensor data to a central dispatch center. The second method (reverse signpost) uses a vehicle transponder to transmit a signal and coded information to a wayside signpost system, which in turn transmits this information through land lines and/or microwave links to the central dispatch center.
- Loran-C is a land-based navigation system that utilizes low-frequency radio waves to provide navigational signal coverage within the United States and coastal waters. Loran-C signals are transmitted by three to six stations, of which one station serves as the master while the others are designated as secondary stations. Secondary stations are synchronized to the master station and transmit their signal at specified intervals, referenced to the master station. A Loran-C receiver knows the sequence of the transmitted signals and determines its location based on the time difference in the arrival of transmitted signals. Loran-C signals can be degraded by radio-frequency and electromagnetic interference and poor signal coverage (due to line of sight on received signals) in dense urban areas. No new Loran-C AVL systems are expected to be deployed in the future for real-time vehicle tracking.
- Dead-reckoning is the most autonomous of the AVL location technologies since it does not use external systems for determining vehicle location. Dead-reckoning systems utilize odometer and compass readings to determine the distance and direction traveled from a known fixed point. Since vehicle positional accuracy degrades as a function of distance traveled, dead-reckoning systems frequently need to be reset or supplemented by other location technologies such as signposts or Global Positioning Systems (GPS).
- Ground-based radio positioning and paging systems (GBRPS) determine vehicle position by measuring the time difference of signal reception through radio triangulation. The location of the vehicle is determined by obtaining the bearing of the moving vehicle with reference to two or more fixed radio stations which are of a known distance apart. Recent applications of GBRPS systems are being provided by private vendors (communication paging systems) where system costs can be expensive depending upon the frequency of system queries.
- Global Positioning Systems (GPS) determine the location of vehicles by using signals transmitted from a network of 24 satellites to vehicles equipped with onboard GPS receivers. The onboard GPS receiver determines the vehicle's position by

converting the satellite signals into position (pseudo range), velocity (delta range) and time measurements. Signals from four satellites are required by the receiving vehicle to determine its X, Y, and Z position with respect to an earth centered reference coordinate system.

Some of the primary advantages and disadvantages of each automated vehicle location technologies, cited in the Transit Cooperative Research Program (TCRP) Synthesis 24 (AVL Systems for Bus Transit) [Ref. 7], are presented in Table 4-1.

Table 4-1. Advantages and Disadvantages of Various AVL Technologies

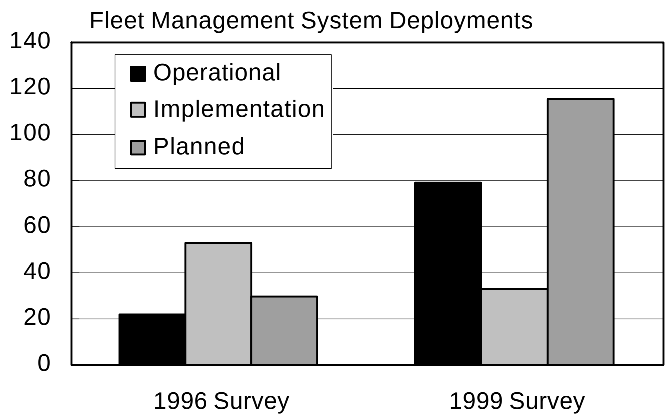
AVL Technology	Primary Advantages	Primary Disadvantages
Signpost/odometer systems	• Low in-vehicle cost • No blind spots or interference • Repeatable accuracy	• Requires well equipped infrastructure (network of signposts) • No coverage outside signpost network • Frequency of vehicle location updates dependent on density of signposts
Dead-reckoning systems	• Relatively inexpensive • Self contained on vehicle (no infrastructure costs) • Only odometer needed (assumes vehicle is on route)	• Accuracy degrades with distance traveled • Requires direction indicator and map matching system to track vehicles off-route
Ground-based radio positioning and paging systems	• Low capital cost • Moderate accuracy • Low maintenance costs	• Monthly service fees that can be relatively high with high frequency of use • Signal attenuation by foliage, tunnels and tall buildings
Global Positioning Systems	• Moderate accuracy • Global coverage • Moderate cost per vehicle	• Signal attenuation by foliage, tunnels and tall buildings • Subject to multipath errors

4.1 Fleet Management System Deployments

Over the past five years, there has been a significant increase in the number of deployments of fleet management systems and in the number of transit systems implementing or planning the implementation of these systems. Figure 4-1 illustrates the growth in the number of transit fleet management system deployments[6], based on the results of two recent surveys[7] [Refs. 4, 5], conducted by the Volpe Center of the transit industry. As shown, the number of fleet management system deployments (currently operational, under implementation, and planned) have more than doubled over the past four to five years, with the largest increases in the number of deployments that are currently operational and those that are being planned.

[6] Fleet Management Systems refer to the deployment of AVM/AVL, advanced vehicle communications, and centralized fleet dispatch and control systems.

[7] The survey entitled: 'Advanced Public Transportation Systems Deployment in the United States', Volpe Center, January 1999 surveyed a total of 551 transit agencies covering the time period July,1998 to December,1998. The previous survey, dated August 1996, surveyed a total of 464 transit agencies covering the time period July,1995 to December,1996.



Fleet Management Deployments

	1996 Survey	1999 Survey
Operational	22	79
Implementation	53	33
Planned	30	116
Total	105	228

Figure 4-1. Fleet Management System Deployments

Of the total (228) fleet management deployments, that were identified in the most recent survey, 68% of the transit system deployments of AVL systems are using or are planning to use GPS/DGPS technology (Figure 4-2). The application of AVL signpost, deadreckoning and other technologies represent approximately 11% of all deployments (operational, under implementation and planned); while 20% of the planned deployments have not identified the type of AVL technology that will be implemented. The TCRP Synthesis 24 (AVL Systems for Bus Transit) [Ref. 7], in their survey of AVL deployments, indicates that GPS or differential GPS (DGPS) is the clear choice for sensor technology and that the vast majority of new projects that are in the feasibility study, planning and design stages will be GPS/DGPS based systems. The TCRP survey further identified that transit agencies, that procured their AVL system in the 1980s or early 1990s, are choosing new signpost technologies to upgrade their existing signpost systems because of established institutional and operational procedures.

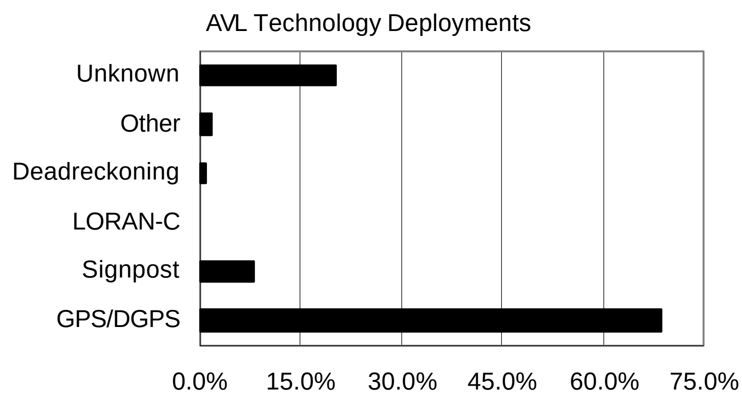
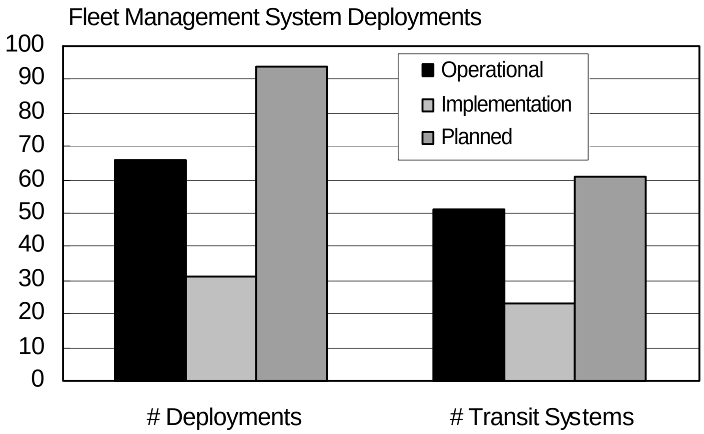


Figure 4-2. AVL Technologies

As a basis for estimating the current and projected fleet management system benefits, this analysis considered[8] a total of 191 deployments of transit fleet management systems that are currently operational, under implementation or planned over the next five years. Figure 4-3 shows the stratification of the APTS fleet management system deployments and the corresponding number of transit systems that have fleet management systems operational, under implementation, and planned. Of the total 191 deployments considered over the 135 transit agencies, 35% are currently operational, 16% are under implementation, and the remaining 49% are planned for deployment.

[8] The selection of fleet management system deployments considered in the analysis was made based on the availability of transit system characteristic data reported within the FTA's 1997 National Transit System database.



Fleet Management System Deployments

	Number of Deployments	Number of Transit Systems
Operational	66	51
Implementation	31	23
Planned	94	61
Total	191	135

Figure 4-3. Fleet Management System Deployments Considered in the Analysis

A breakdown of these deployments by transit mode, along with the corresponding size of the transit vehicle fleet, is presented in Table 4-2.

Table 4-2. Fleet Management System Deployments Considered in the Analysis

	Operational		Under Implementation		Planned		Total	
Mode	Number of Deployments	Fleet Size	Number of Deployments	Fleet Size	Number of Deployments	Fleet Size	Number of Deployments	Fleet Size
FRB	41	13,685	19	9,165	51	9,288	111	32,138
DRT	17	1,396	11	895	37	4,454	65	6,745
CR	3	1,112	1	71	1	56	5	1,239
HR	2	268	0	0	1	59	3	327
LR	3	222	0	0	4	332	7	554
Total	66	16,683	31	10,131	94	14,189	191	41,003
FRB = Fixed Route Bus, DRT = Demand Responsive Transit, CR = Commuter Rail, HR = Heavy Rail, LR = Light Rail								

A listing of the fleet management system deployments (operational, under implementation, and planned) considered in this analysis is presented within Appendix B of this report.

4.2 Fleet Management System Benefits

The primary benefits most often cited[9] [Ref. 8] by transit agencies with the deployment of fleet management systems include:

- *Increased transit safety and security.* The integration of AVM and advanced vehicle communications technologies can significantly increase the safety and security of both transit drivers and riders. For many transit agencies, the issues of transit safety

[9] Under the auspices of the DOT's Intelligent Transportation Systems Program, the Federal Transit Administration established an Advanced Public Transportation Systems 'stakeholders forum' of industry and government representatives to help advise and guide the FTA in developing and implementing a Transit ITS program. One of the initial activities of this group was the establishment of a Transit-ITS Impacts Matrix, that would serve as a mechanism to collect and organize information on the benefits, costs and application results of transit ITS technologies. This matrix can be located at the following internet site: http://idf.mitretek.org/its/aptsmatrix.nsf .

and security were primary factors in the decision to install AVM/AVL transit management systems. The ability to monitor vehicle movements and to respond to silent alarms has increased the sense of transit security and improved the response to transit emergencies and incidents. Many transit agencies have reported reductions in emergency response times of up to 40%. The Kansas City Area Transit Authority reported that, with the implementation of an AVL system, emergency response times for driver assistance calls have been reduced to three or four minutes from previous average response times of seven to fifteen minutes. There have been a number of other reported agencies (Denver RTD, Maryland MTA) that have cited the benefit of having the location of transit vehicles in order to respond to accidents, crimes or other situations that warrant the quick response of police and emergency personnel. [Refs. 9, 10].

- *Improved operating efficiency.* Another major benefit area associated with fleet management systems is improved efficiency in the operations of transit vehicle fleets and drivers. Most transit agencies incorporate layover times at the end of each trip, with the objective of preventing delays that develop in one trip from carrying over into the next trip. On average, it is reported [Ref. 11] that the time transit vehicles/drivers spend in layover can cause a vehicle to be in non-revenue service 20%-25% of the time. By knowing the precise location of its vehicle fleet, transit dispatch centers can monitor and control fleet movements, reduce headway dispersion and platooning of vehicles, and reduce vehicle layover and non-revenue deadhead times. Preliminary results from initial fleet management system deployments have provided reductions in overall transit fleet requirements and non-revenue service time and mileage. The Kansas City Area Transportation Authority (KCATA) reported a 23% improvement in schedule adherence, that allowed KCATA to revise their current schedules and reassign its vehicles to service other transit routes. By using segmented running times, slack time in transit schedules was reduced. The new schedules resulted in a reduction of three base period buses and an additional four buses in the PM-peak period. These reductions represent a total 1.5% reduction in the base fleet and an additional 2% reduction for the PM-peak period fleet [Refs. 7, 12]. Other transit agencies have reported [Ref.13] reductions in fleet requirements ranging from 2% to 5% as a result of efficiencies in fleet utilization.

- *Improved transit service*. Transit management systems provide transit agencies increased flexibility to monitor and control their transit fleets and ensure adherence to published transit schedules. Many deployments of AVM/AVL systems have demonstrated improvements in overall schedule adherence. The Maryland Mass Transit Administration (MTA) reported a 23% improvement in on-time performance in a test of AVL equipped buses on selected routes. The Maryland MTA has recently expanded its AVL fleet management operations with a new DGPS system; currently 380 of the agency's 868 vehicle fleet are AVL equipped. The MTA expects, that by the fourth to sixth year of operation, it will see reductions in the number of vehicles required to maintain the current level of service. The MTA expects savings of $2 - $3 million per year by purchasing, operating and maintaining fewer vehicles [Ref. 14]. Milwaukee Transit System (MTS), which has completed installation of a GPS-based AVL system on all its vehicles (543 buses and 60 support vehicles) in 1996, has reported that their AVL system has helped them provide "better and more reliable service to their customers." MTS has reported that the number of off-schedule[10] buses has been reduced by 40% during the period that their schedule adherence function was not fully operational on all buses [Ref. 3]

- *Improved transit information*. AVM/AVL system applications also provide benefits in the form of improved transit information and integration with other APTS technologies. Many transit agencies are implementing AVM/AVL systems to provide information for their transit route planning and scheduling functions and their transit information systems. In Denver, Baltimore, Kansas City, and Seattle, AVM/AVL deployments are being used to develop tighter, more efficient schedules and to reduce the time and costs associated with conducting route schedule adherence checks. At the Tri-County Metropolitan Transportation District (Tri-Met) in Portland OR, a DGPS-based AVL system has been operational since 1998 on approximately 650 fixed-route and 150 demand responsive transit vehicles. Tri-Met utilizes its AVL system to better manage their service, respond to disruptions, and as a source of management information data. Tri-met has noted improvements in on-time performance, as well as reductions in headway variability, schedule variability, and 'excess customer wait time' [Ref. 14]. Other transit systems are employing AVM/AVL systems to provide up-to-date schedule information to its transit riders through its transit information systems. Integration of transit fleet management data with public transit information systems has been demonstrated in a number of sites including Minneapolis, Seattle, Atlanta, and San Francisco. At the Denver Regional Transportation District (RTD), which has had an operational AVL system on all of its fixed route bus fleet since 1995, has plans for the integration and dissemination of bus location data once its AVL schedule adherence function is fully operational. Current RTD plans are to establish bus schedule and AVL transit traffic update information on transit information kiosks in major transit terminals, at the Colorado DOT Traffic Operations Center, and on the Internet [Ref. 3].

This analysis estimated the benefits of the fleet management system deployments in the form of savings in transit fleet operations. These benefits were derived based on a one-time reduction in fleet operating costs, following deployment of an fleet management systems, and the annual recurring savings in fleet operating costs as a result of the assumed fleet efficiency savings. Estimated fleet management system benefits (minimum, most likely, and maximum) were developed based on the following assumed variables (Table 4-3) and equation outlined below.

Table 4-3. Transit Fleet Management Systems Analysis Assumptions

Variable	For the period 1997-2000	Minimum Estimate	Most Likely Estimate	Maximum Estimate
% annual increase in: • Transit operating costs	3.0%	2.0%	3.0%	5.0%
• Transit service (VRM)	2.0%	2.0%	3.0%	5.0%
% savings in transit (non-revenue) vehicle miles		4.0%	6.0%	8.0%

[10] According to MTS operations, off-schedule buses are classified as those vehicles that are running more than one minute early or three minutes late of scheduled operations.

[Reduced Transit Fleet Operating Costs] $_{Year}$

$$= [\text{operating cost per mile}]_{Year} \times [\text{annual non-revenue vehicle miles}]_{Year} \times [\text{\% savings in transit (non-revenue) vehicle miles}].$$

where:

[operating cost per mile]$_{Year}$	Represents the transit agency's vehicle operating cost per vehicle mile (includes only costs of fleet operations). For operational deployments, it reflects the projected fleet operating cost per mile in year 2000. For deployments under implementation or planned, it reflects projected fleet operating costs per mile in years 2003 and 2005, respectively.
[annual non-revenue vehicle miles]$_{Year}$	Represents the transit agency's projected annual non-revenue vehicle miles[11] in years 2000, 2003 and 2005, for deployments that are operational, under implementation, and planned, respectively.
[% savings in transit (non-revenue) vehicle miles].	Represents the assumed reduction in transit (non-revenue) vehicle miles resulting from the implementation of fleet management systems. The percentage savings is based on a probability distribution based on minimum, most likely and maximum values.
Year	Represents year 2000 for operational deployments, year 2003 for deployments under implementation, and year 2005 for planned deployments.

This analysis projected that the total benefits, over the next ten years, for the fleet management system deployments would range from $810.8 million (minimum estimate) to as high as $1.6 billion (maximum estimate). The projected most likely estimate of the total fleet management benefits is $1.2 billion. These benefits are expressed in discounted, year 2000 present value dollars.

Table 4-4 and Figure 4-4 present the projected minimum, most likely and maximum benefits (in discounted, year-2000 dollars) for fleet management system deployments that are currently operational, under implementation and planned for deployment.

Table 4-4. Fleet Management System Benefits (in Millions of discounted Y2000 dollars)

	# FMS Deployments	FMS Benefits Minimum Estimate	FMS Benefits Most Likely Estimate	FMS Benefits Maximum Estimate
Operational	66	$557.2	$821.5	$1,089.5
Implementation	31	$153.9	$226.1	$301.9
Planned	94	$99.7	$146.9	$200.5
Total	191	$810.8	$1,194.5	$1,591.9

[11] An agency's annual non-revenue vehicle miles represents the difference in the total annual vehicle miles operated and the annual vehicle miles operated in revenue service for a given mode of transit operation.

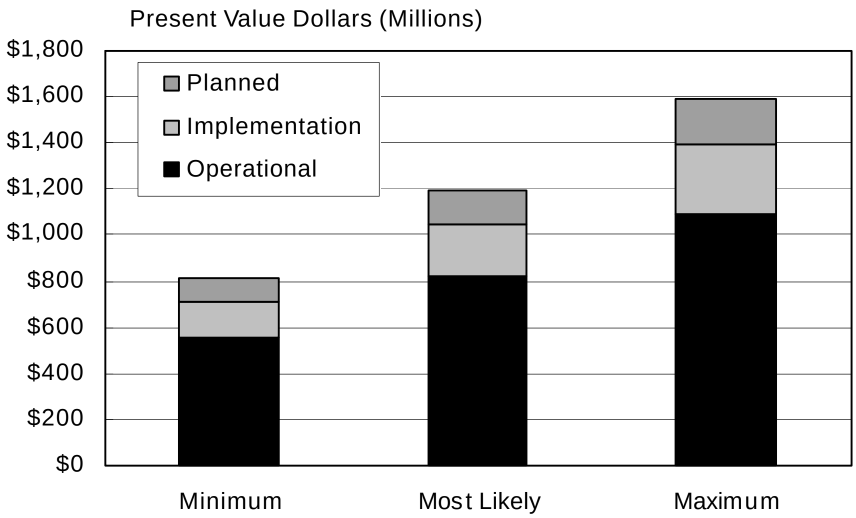
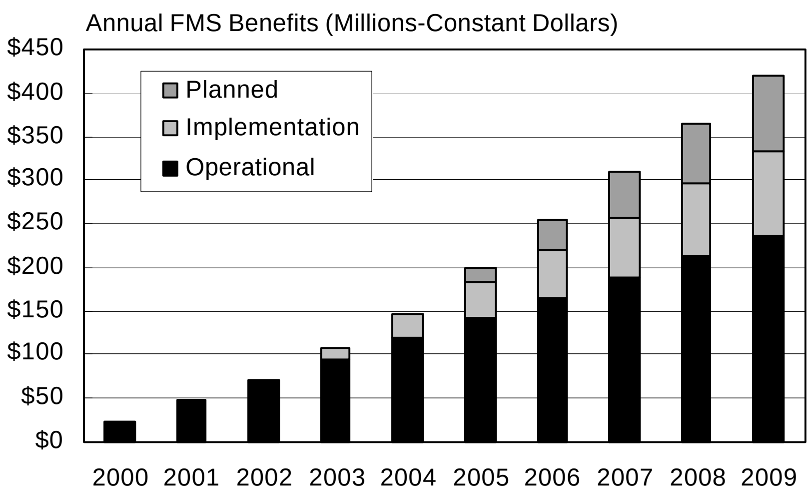


Figure 4-4. Fleet Management Benefits

Sixty-nine percent of the total projected benefits for the fleet management systems are derived as a result of the currently operational deployments. Whereas, the fleet management system deployments that are currently under implementation and planned represent 19% and 12%, respectively, of the total benefits.

Figure 4-5 illustrates the distribution of the projected annual benefits, over the ten year analysis period, for the most likely fleet management systems estimate. The annualized benefits reflected in this figure are expressed in millions of constant, year 2000 dollars.



Total Annual FMS Benefits
(Millions Constant Dollars)

Year	Benefits
2000	$24
2001	$47
2002	$71
2003	$108
2004	$146
2005	$201
2006	$256
2007	$311
2008	$366
2009	$421
Total	$1,950

Figure 4-5. Annual Fleet Management System Benefits

A summary of the projected minimum, most likely and maximum fleet management systems benefits in constant and discounted, year 2000 dollars is presented in Table 4-5. This table also identifies the distribution of the fleet management system benefits, by transit mode and by phase of deployment (operational, under implementation and planned). Over 90% of the total fleet management benefits are accrued by fixed-route bus deployments. Commuter rail transit and demand responsive transit deployments represent 5% and 4%, respectively, of the total benefits. Projected deployments for heavy rail and light rail operations represent only 1% of the total fleet management benefits.

Table 4-5. Summary of Projected Fleet Management System Benefits

Minimum Estimate	Constant Year 2000 Dollars (Millions)				Discounted Present Value Dollars (Millions)			
	Operational	Implementation	Planned	Total	Operational	Implementation	Planned	Total
Fixed Route Bus	$783.2	$253.7	$164.4	$1,201.3	$494.7	$148.7	$91.8	$735.2
Demand Responsive	$32.8	$7.4	$10.5	$50.7	$20.7	$4.4	$5.8	$30.9
Commuter Rail	$54.8	$1.4	$0.8	$57.1	$34.6	$0.8	$0.5	$35.9
Heavy Rail	$5.6	$0.0	$0.1	$5.6	$3.5	$0.0	$0.0	$3.5
Light Rail	$5.8	$0.0	$2.8	$8.5	$3.6	$0.0	$1.5	$5.2
Total	$882.2	$262.5	$178.5	$1,323.3	$557.2	$153.9	$99.7	$810.8
Most Likely Estimate	Constant Year 2000 Dollars (Millions)				Discounted Present Value Dollars (Millions)			
	Operational	Implementation	Planned	Total	Operational	Implementation	Planned	Total
Fixed Route Bus	$1,154.7	$372.9	$242.2	$1,769.7	$729.3	$218.5	$135.2	$1,083.1
Demand Responsive	$48.4	$10.9	$15.4	$74.7	$30.6	$6.4	$8.6	$45.6
Commuter Rail	$80.8	$2.1	$1.3	$84.2	$51.1	$1.2	$0.7	$53.0
Heavy Rail	$8.2	$0.0	$0.1	$8.3	$5.2	$0.0	$0.0	$5.2
Light Rail	$8.5	$0.0	$4.1	$12.6	$5.4	$0.0	$2.3	$7.7
Total	$1,300.7	$385.8	$263.0	$1,949.5	$821.5	$226.1	$146.9	$1,194.5
Maximum Estimate	Constant Year 2000 Dollars (Millions)				Discounted Present Value Dollars (Millions)			
	Operational	Implementation	Planned	Total	Operational	Implementation	Planned	Total
Fixed Route Bus	$1,531.3	$497.8	$330.6	$2,359.8	$967.2	$291.8	$184.6	$1,443.6
Demand Responsive	$64.2	$14.6	$21.1	$99.8	$40.5	$8.5	$11.8	$60.8
Commuter Rail	$107.2	$2.8	$1.7	$111.7	$67.7	$1.6	$1.0	$70.3
Heavy Rail	$10.9	$0.0	$0.1	$11.0	$6.9	$0.0	$0.1	$6.9
Light Rail	$11.3	$0.0	$5.6	$16.9	$7.1	$0.0	$3.1	$10.2
Total	$1,724.9	$515.2	$359.1	$2,599.1	$1,089.5	$301.9	$200.5	$1,591.9

4.3 Fleet Management System Costs

The implementation of transit fleet management systems are significant investments. As reported the TCRP Synthesis 24 [Ref. 7], a number of transit agencies, who were planning to deploy fleet management systems, have had to pull-back their system acquisition procurements and re-scale their plans because of program funding issues. In certain cases, where funding for various fleet management system deployments were expected to be on the order of a few million dollars, cost proposals for the acquisition and deployment of these systems were received from vendors at three or four times the original cost estimates.

The TCRP Synthesis 24 outlines a number of institutional and cost issues to be addressed with the implementation of transit fleet management systems. Primary among the issues identified are: system planning, system design, acceptance testing, training, and system evaluation.

The TCRP Synthesis 24 also presents the results of a survey of transit agencies that had operational fleet management systems or have secured funds to procure an AVL system. Representative costs of AVL deployments and various AVL system components (i.e., bus location technology, vehicle control units, control center costs, software costs, etc.) are presented based on the survey results and information derived from the FTA's APTS-State of the Art (SOA) reports. Presented in Table 4-6 is a summary of fleet management system costs for deployments that are either currently operational or planned. The data sources for this table are the TCRP Synthesis 24, the APTS SOA reports, and the transit surveys on APTS system deployments. As shown, there is a wide variation in AVM/AVL costs, depending upon the type of location technology and the types of integrated system features planned (i.e., schedule adherence function, computerized dispatching, engine probe, silent alarm, passenger counters, traffic signal prioritization, etc.). One of the primary cost drivers of AVM/AVL systems is the cost of integrated radio communications and/or onboard communication data terminals.

The TCRP Synthesis 24 indicated the signpost and GPS-based location systems cost about the same. Further, the Synthesis survey results indicate that, on average, the fleet management systems cost about $13,700 per vehicle. Smaller transit agencies tend to pay more per vehicle because the overall costs for system infrastructure and control system software have to be spread over fewer vehicles. Based on the survey responses, the minimum cost for small AVL system deployments (fleet sizes of 30-40 vehicles), requiring a communications system, is about $350,000. These costs will vary depending on the sophistication of the control software, and would not necessarily include costs for training and system maintenance [Ref. 7].

In a study conducted in 1994, the National Urban Transit Institute investigated the benefit and economic feasibility of AVL and communications systems for bus transit. This study conducted a break-even analysis to determine the feasibility of cost recovery for AVL deployments based on savings as a result of reductions in schedule slack time and fleet reductions. This study found that in order for a representative transit agency to recover its fleet management system investment costs it must reduce its fleet size by 2.3% or reduce its revenue miles by nearly 1%. The same savings could be achieved with a 2.3% increase in revenues or 2.3% increase in transit ridership [Ref. 15].

Table 4-6. Fleet Management System Costs

State	Transit System	Total Vehicle Fleet MB	DRT	CR	HR	LR	AVL Technology	System Features Radio	SA	CAD	EP	Alarm	SP	PI	APC	System Cost	Notes
AZ	Phoenix-RPTA	75					GPS			✓		✓				$5.1 M	
AZ	Tucson-Sun Tran	203					GPS	n/a	✓		✓	✓		✓	✓	$3.5 M	
CA	Contra Costa-Connection	116					GPS									$234.0 K	$234K/ part of $1.4 mil system
CA	LA-Access		243				GPS									$2.0 M	
CA	LA-LACMTA-Metro	2,413			30	69	SO, DGPS	✓		✓	✓	✓	✓			$12.0 M	installation for 2,085 vehicles
CA	LA-Santa Monica	135					OTR					✓				$131.8 K	installation for 135 vehicles
CA	Oakland-AC Transit	694					GPS	n/a		✓	✓	✓		✓	✓	$14.5 M	installation for 717 vehicles
CA	Riverside-RTA	107					DK									$180.0 K	
CA	San Francisco-Muni	454				136	SO	n/a				✓				$3.0 M	
CA	San Joaquin-Smart	95	36				DGPS									$900.0 K	
CA	Santa Clara - Outreach		155				DGPS			✓		✓				$800.0 K	
CO	Denver-RTD	849				17	DGPS	✓		✓		✓		✓		$1.2 M	installation for 900 vehicles
FL	Orlando-LYNX	205					GPS					✓				$250.0 K	
FL	Tampa-Hartline	189					SO					✓				$1.6 M	
GA	Atlanta-MARTA	783			238		DGPS	n/a		✓		✓		✓	✓	$7.0 M	installation for 250 vehicles
IA	Five Seasons Trans	40	33				GPS									$750.0 K	
IA	Sioux City-STC	36	26				U			✓						$100.0 K	
IL	Chicago-CTA/Dupage		160				OTR									$70.0 K	$70,000 hardware. $3500 monthly fee.
IL	Chicago-RTA-CTA	1,882					DK	✓	✓	✓	✓	✓	✓		✓	$33.0 M	Includes $13 million for radio.
KY	Louisville-TARC	306					SO			✓	✓	✓			✓	$2.5 M	installation for 257 vehicles
MD	Montgomery County DPW&T	230					DGPS	✓	✓	✓		✓	✓			$5.0 M	installation for 130 vehicles
MD	Baltimore-Maryland-MTA	880		134			GPS	✓	✓	✓		✓				$8.9 M	installation for 844 vehicles
MI	Ann Arbor-AATA	69	47				SO			✓	✓	✓		✓		$2.3 M	
MI	Detroit-SMART	300	150				GPS	✓	✓	✓	✓	✓	✓			$2.8 M	installation for 400 vehicles
MI	Lansing-CATA	68					GPS									$500.0 K	
MN	Minneapolis-St. Paul	894					GPS	✓		✓				✓	✓	$7.0 M	
MO	Kansas City-KCATA	252					SO	✓	✓	✓		✓	✓		✓	$2.3 M	installation for 245 vehicles
NC	Raleigh-CAT	50	11				U	✓		✓		✓		✓		$600.0 K	installation for 52 vehicles
NJ	New Jersey Transit	2,098		944			SO, GPS	✓	✓	✓	✓	✓		✓	✓	$31.0 M	installation for 1990 vehicles
NM	Albuquerque-SunTran	130	43				GPS	✓	✓		✓	✓		✓	✓	$3.5 M	installation for 200 vehicles
NY	Buffalo-NFTA	322					GPS	✓		✓	✓	✓		✓	✓	$9.0 M	$9.0 M includes radio
NY	NY-MTA-NYCTA	3,867					DGPS		✓	✓	✓	✓		✓		$5.0 M	$5 million for 170 buses/4 routes.
NY	NY-Westchester-Liberty	324					SO, GPS		✓	✓		✓				$12.0 - $14.0 M	$12-14 million for entire GPS system.
OH	Akron-Metro	138					GPS									$65.0 - $150.0 K	14 vehicle demonstration project
OH	Cincinnati-SORTA	389	41				GPS	✓		✓	✓	✓		✓		$7.3 M	Includes radios.
OH	Cleveland-LAKETRAN	30	64				GPS			✓		✓		✓		$951.0 K	
OH	Greater Cleveland RTA	715	136		59	47	DGPS	✓	✓	✓	✓	✓				$20.0 M	system includes radios
OH	Youngstown-WRTA	43	6				(GPS)									$315.0 K	$315,000 for radios and AVL
OR	Portland-Tri-Met	625	149				DGPS			✓		✓	✓		✓	$6.7 M	installation for 630 vehicles
PA	Beaver County-BCTA	14	25				[GPS]	✓				✓		✓		$201.2 K	
PA	Scranton-Colts	35					GPS	✓	✓	✓		✓		✓		$385.0 K	
TX	Dallas-DART	543	96				GPS	n/a		✓	✓	✓		✓		$16.4 M	
TX	El Paso-Sun Metro	165	86				U			✓		✓			✓	$3.5-3.9 M	Design phase of a study.
TX	Houston-Metro	1,202	1,986				U			✓	✓	✓		✓		$20.0 M	installation for 1,750 vehicles
TX	San Antonio-VIA	498	423				DGPS									$13.5 M	$13.5 million for radio and AVL.
VA	Norfolk-TRT	168					U	n/a			✓	✓				$2.0 M	installation for 150 vehicles
VA	Prince William-PRTC	75					GPS			✓		✓				$5.1 M	
WA	Bremerton-Kitsap Transit	119	47				GPS	n/a		✓		✓	✓	✓		$600.0 K	
WA	Richland-Ben Franklin		62				GPS			✓						$180.0 K	$180,000 (DR only)
WA	Seattle-Metro	1,114					SO	✓	✓	✓		✓	✓	✓	✓	$15.0 M	$15 million for AVL, software & radios.
WI	Milwaukee-County	535					DGPS	✓	✓	✓	✓	✓				$8.0 M	

Legend: GPS/DGPS - Global Positioning System; SO - Signpost; DK - Deadreckoning; LC - Loran-C; OTR - Other; U - Unknown
SA - schedule adherence; CAD - computer aided dispatch; EP - engine probe; Alarm - silent alarm; SP - signal prioritization; APC - automated passenger counter.

Source: APTS 1999 Deployment Survey Data; Volpe Center; Transit Cooperative Research Program Report: TCRP Synthesis 24 AVL Systems for Bus Transit

Section 5
Operational Software and Computer Aided Dispatching Systems

The deployment of operational software (OS) and computer-aided dispatching (CAD) systems for fixed route, demand responsive transit and other ride-sharing services has existed in various forms over the past two to three decades. Early deployments of these systems have focused on automated scheduling of transit operations[12] for fixed route bus systems and vehicle dispatching systems as an outgrowth of automated dispatching services being implemented within the taxi industry.

Today, operational software and computer-aided dispatching systems are being expanded to automate, streamline and integrate many transit functions and modes. These systems are being used for transit service and route planning, for monitoring and control of transit operations, and for providing more accurate information of transit demand and ridership trends. When linked with AVL systems, operational software systems provide real-time dispatching of transit service, faster responses to service disruptions, and improved coordination of service of various transit modes (i.e., fixed-route bus and demand responsive transit services). Operational software and dispatching systems can more accurately identify the existence and location of incidents and can assist transit operators in directing emergency response and in restoring service. OS/CAD systems can provide more reliable service for transit riders, more efficient operations for transit agencies, and increased safety for both vehicle operators and customers.

For fixed route bus systems, operational software systems are being used to track the on-time status of vehicle fleets and in the management of vehicle and control center communications. When linked with AVL and on-board communication technologies,[13] OS systems are being used to reduce the amount of voice communications and to prioritize voice and digital messages from vehicle fleets to transit control centers. With the application of AVL schedule adherence capabilities, operational control software systems are being used to monitor fleet movements and to avoid transit service irregularities such as “bus bunching” or vehicles “running-hot.” Planned OS/CAD system developments are now being directed to incorporate features such as: coordination of transit transfer connections, transit itinerary planning, and the application of expert systems to handle service disruptions and service restorations.

For rail transit systems, the application of operational software systems are generally linked with existing or upgraded rail supervisory control and data acquisition systems (SCADA), which include rail wayside monitors for switches, signals and interlockings; wayside sensors for electrical and mechanical subsystems; a communications backbone; and software processing

[12] Early developments of transit operational software systems were directed towards automating various transit scheduling functions including: vehicle scheduling, driver run-cutting, driver bid processing, timekeeping and other fleet management activities.
[13] Such as on-board vehicle logic units (VLUs) and mobile data terminals (MDTs) that allow bus operators to send and receive digital messages.

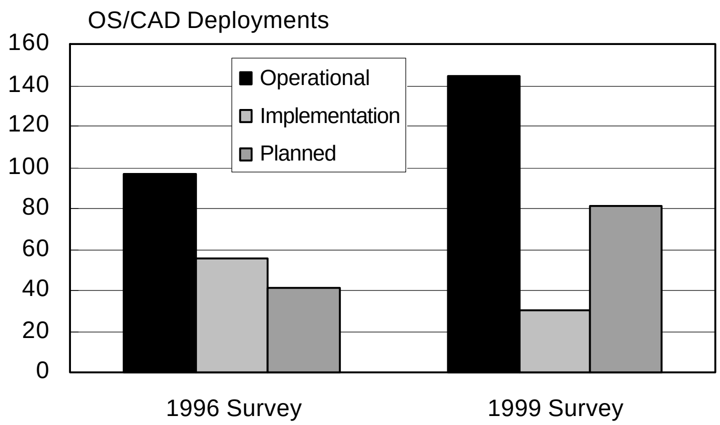
and display capabilities. Rail operational software systems are now using SCADA data with other vehicle control systems such as automatic train control (ATC), automatic vehicle identification (AVI), traffic signal loop detectors (for light-rail operations), and automated train dispatch systems. Rail operational software systems can be used to monitor and improve train dispatching operations, to ensure operator compliance with train speed and signal operations, to respond to service disruptions, and to facilitate service restoration. Rail OS/CAD systems are also being expanded to ensure coordination of schedules and passenger transfers at rail and fixed-route bus transfer points and to provide real-time information to transit traveler information systems.

For demand responsive transit (DRT) operations, the applications of operational software and computer-aided dispatching systems are being directed to improve the operations of small urban and rural transit systems and to improve the services to many groups of citizens (e.g., the elderly and the disabled) that require specialized transportation services not readily available by fixed-route bus and rail systems. The scheduling of demand responsive transportation services is highly complex because of the shared-ride nature of the trips, the special needs (e.g., wheelchair accessible vehicles) of the passengers, and the constraints[14] under which transit agencies must comply to provide such services. The scheduling of DRT transit services entails the recording and scheduling of incoming passenger reservations for on-demand, real-time trips or on advance reservations for trips to be taken the next day, week, or month. Passengers, vehicles and, in some cases, drivers are scheduled based upon the types of service required, time/day of week, and locale of trip origins and destinations. The vehicle routes and schedules are optimized by minimizing travel time or distance subject to the constraints of vehicle capacity and passenger desired pickup and drop-off times.

5.1 Operational Software and Computer Aided Dispatching System Deployments

The recent study of APTS technology applications [Ref. 5] identified a total of 255 deployments of operational software and computer aided dispatching systems that are operational, under implementation, or planned for deployment within the transit industry. Figure 5-1 illustrates the growth in the number of OS/CAD deployments, based on the two most recent surveys conducted by the Volpe Center on APTS technology deployments [Refs. 4, 5]. As shown, the total number of OS/CAD deployments (operational, under implementation, and planned) increased by 30% over the past five years with the largest increases in deployments that are currently operational and those that are planned.

[14] Many of the constraints include compliance to meet the requirements of the Americans with Disabilities (ADA) Act, and with local, state, and Federal statutes dealing with the validation of passenger requirements for specialized transportation services and/or subsidized fares.

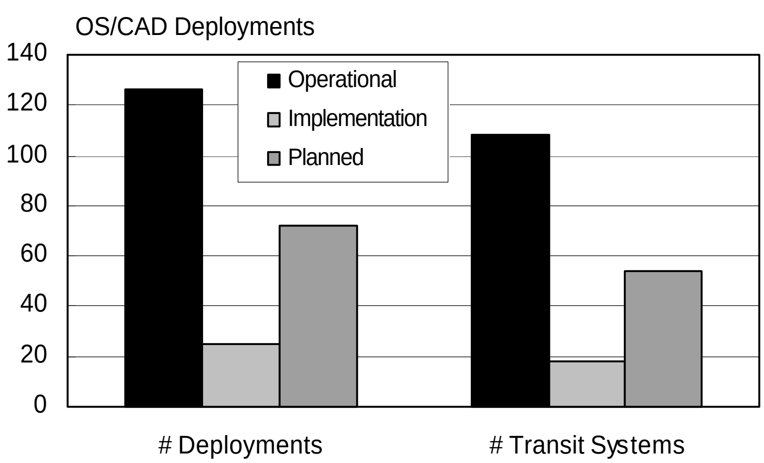


APTS OS/CAD Deployments	1996 Survey	1999 Survey
Operational	97	144
Implementation	56	30
Planned	41	81
Total	194	255

Figure 5-1. Growth in OS/CAD Deployments

As a basis for estimating current and projected benefits of operational software and computer-aided dispatch systems, this analysis considered a total of 223 deployments of these systems that are currently operational, under implementation, or planned over the next five years.

Figure 5-2 shows the stratification of the OS/CAD system deployments and the corresponding number of transit systems that have these systems operational, under implementation, and planned. Of the total 223 deployments considered over the 180 transit agencies, 57% are currently operational, 11% are under implementation, and the remaining 32% are planned for deployment.



OS/CAD Deployments	Number of Deployments	Number of Transit Systems
Operational	126	108
Implementation	25	18
Planned	72	54
Total	223	180

Figure 5-2. OS/CAD Deployments Considered in Analysis

A breakdown of these deployments by transit mode, along with the corresponding size of the transit vehicle fleet, is presented in Table 5-1.

Table 5-1. OS/CAD System Deployments Considered in the Analysis

Mode	Operational		Under Implementation		Planned		Total	
	Number of Deployments	Fleet Size	Number of Deployments	Fleet Size	Number of Deployments	Fleet Size	Number of Deployments	Fleet Size
FRB	29	8,644	13	5,250	35	9,554	77	23,448
DRT	86	4,576	9	470	33	1,538	128	6,584
CR	5	3,620	0	0	1	34	6	3,654
HR	4	1,227	0	0	2	5,854	6	7,081
LR	2	183	3	139	1	69	6	391
Total	126	18,250	25	5,859	72	17,049	223	41,158

FRB = Fixed Route Bus, DRT = Demand Responsive Transit, CR = Commuter Rail, HR = Heavy Rail, LR = Light Rail

A listing of the OS/CAD system deployments (operational, under implementation, and planned) considered in this analysis is presented within Appendix B of this report.

5.2 Operational Software and Computer Aided Dispatching System Benefits

The primary benefits reported by transit agencies or cited from evaluations of the operational software and computer-aided dispatch systems include:

- *Increased efficiency in transit operations*. Operational software and computer-aided dispatch systems can improve the efficiency of transit operations through more efficient scheduling of transit resources (vehicles and drivers) to passenger trip requests. OS/CAD systems increase the utilization of vehicle fleets, reduce non-revenue vehicle miles (vehicle hours) and reduce the costs of fleet dispatching. For many demand-responsive transit operations, OS/CAD systems validate passenger trip requests for provided transportation services, certify pre-approved or subsidized fare payments, and record and bill agencies or passengers for the services provided. In Santa Clara County, CA, a paratransit provider, OUTREACH, has recently completed a Federal and state funded demonstration program to implement an integrated automated scheduling and dispatching system with a digital geographic database and a GPS-based AVL system. The OUTREACH system scheduled passenger trips through a combination of scheduled fixed-route bus and paratransit trip segments. Passenger trip requests are analyzed to determine if the trip origin or destination is within a corridor serviced by fixed route buses. Trips are scheduled by segmenting the passenger trip into one or more paratransit and/or fixed route trip segments. Vehicle schedule adherence was monitored, via AVL, to ensure coordinated transfers on all passenger trip segments. An evaluation of this system, conducted by the University of California at Berkeley, found that without the automated trip scheduling system Outreach would not have been able to accommodate the increases in the demand for paratransit services to meet full American with Disabilities Act (ADA) compliance in 1997. The Santa Clara OUTREACH system was able to meet this demand by increasing the number of shared rides from 38% to 55% and reducing its fleet size from 200 to 130 vehicles. These improvements in operations resulted in a savings of nearly $500,000 in the first year of service [Ref. 3]. The Winston-Salem Transit Authority (WSTA), through its Trans-Aid division, provides demand responsive transportation services in the greater Winston-Salem and Forsyth County area in North Carolina. In 1994, Tans-Aid installed a computer-aided dispatching system to schedule DRT services for over 120,000 passenger trips per year and its fleet of 19 small buses. With the installation of their CAD system, Trans-Aid showed an increase in ridership on its rural routes (17 to 40 passengers per day), a 12% increase in its urban ridership, and a 5.6% reduction in vehicle-hours (even though vehicle-miles increased by 8.5%). While total operating costs for the Trans-Aid DRT operations increased (because of the increased service), their operating cost per vehicle-mile dropped by 8.5% to $1.93/vehicle-mile and their operating cost per passenger trip dropped by 2.4% to $5.64/passenger trip [Refs. 16, 17]. In another OS/CAD application, the Blacksburg Transit Authority, which provides demand responsive and subscription transportation services in Blacksburg, VA, implemented an automated scheduling and AVL system on its fleet of 29 fixed-route and eight DRT vehicles in 1998. With the application of these technologies, Blacksburg Transit has seen a 50% efficiency improvement in the scheduling of its passenger trips from 0.8 passengers per hour to nearly two passengers per hour. Overall system capacity was improved by providing service to a greater number of passengers with the same number of vehicles and drivers [Ref. 17].

- *Improved transit service and customer convenience*. Operational software and computer-aided dispatching systems provide improved transit service and convenience to customers in the form of improved response times in placing DRT trip requests, improved reliability in achieving estimates of predicted pickup/drop-off times, reduced trip travel times, and increased flexibility in the scheduling of desired services. For fixed-route bus and rail transit services, operational software systems help maintain transit schedule adherence and coordinated transfers to minimize the wait time for transferring passengers. In January 1999, the Chicago Regional Transportation Authority (RTA) initiated a coordinated transfer program, that when fully implemented, will be the first large scale, inter-agency transit coordinated-transfer program of its kind. Participating agencies include the Chicago Transit Authority, Pace (suburban bus operations), Metra (commuter rail), and the Illinois DOT. Potential benefits from this program would be in the form of improved customer information of planned transfers, reduced transfer wait times, and improved, more consistent inter-carrier connections [Ref. 14]. The Montgomery County DPW Transit Division, in Maryland, has installed a DGPS-based AVL system and computerized dispatching system on about half of its 225 bus fleet. The system features an "intelligent vehicle" technology that continuously calculates vehicle positions and determines schedule adherence. Bus operators are continuously informed of their schedule adherence, via on-board mobile data terminals, and provides transit dispatch coordinators with information to adjust and restore scheduled transit services [Ref. 3]. In New York, the New York City Transit Authority (NYCTA) is developing a Computer Aided Support Management (CASM) decision support system to address schedule adherence and headway maintenance problems. CASM is being designed to process information, from their AVL system, and develop multiple service restoration strategies to help NYCTA dispatchers maintain service regularity and quickly respond to any service disruptions [Ref. 14].

- *Increased compliance with transit ADA requirements*. The Americans with Disabilities Act (ADA) of 1990 requires fixed-route transit systems to provide complementary demand-responsive transit services for passengers, who live/work within a three-quarter mile radius of a transit route, and who are unable to board a conventional transit vehicle. In addition, the ADA requirements stipulate that transit agencies are required to respond to previous-day reservations and that passengers cannot be on board the vehicle longer than one hour. Demand responsive transit CAD systems facilitate the scheduling and handling of specialized transportation requests, and ensure compliance with ADA requirements. Many systems are implementing new scheduling and dispatching software for improving the efficiency and increase the passenger occupancy of their demand responsive vehicles operating in a shared-ride mode. In addition to advance trip reservations and immediate requests for services, DRT-CAD systems are being expanded to include route deviation services, intermodal and inter-agency connections. In 1998, the FTA awarded a $200,000 grant to three rural counties (Flagler, St. Johns and Putnam counties) in Florida to implement a paratransit software system as part of their inter-county social service coordination project. The demonstration project is intended to show cost-savings and efficiencies in the use of ITS technologies in rural communities, expand the use of ITS technologies to promote intra-coordination of community based transportation services, and integrate rural systems with nearby urban mass transit systems. The demonstration project is administered by the Florida Commission for the Transportation Disadvantaged and is being expanded to include two additional counties (Marion and Alachua) [Ref. 14].

This analysis estimated the benefits of the OS/CAD system deployments in the form of savings in transit fleet operations and in the improved scheduling of fleet resources to service scheduled passenger trips. Benefits were derived based on a one-time reduction in fleet operating costs, following deployment of an OS/CAD system, and the annual recurring savings in fleet operating costs as a result of the assumed fleet efficiency savings. Estimated OS/CAD system deployment benefits (minimum, most likely, and maximum) were developed based on the following assumed variables (Table 5-2) and equation outlined below.

Table 5-2. OS/CAD Analysis Assumptions

Variable	For the period 1997-2000	Minimum Estimate	Most Likely Estimate	Maximum Estimate
% annual increase in: • transit operating costs	3.0%	2.0%	3.0%	5.0%
• transit service (VRM)	2.0%	2.0%	3.0%	5.0%
% savings in transit (non-revenue) vehicle miles		4.0%	6.0%	8.0%

$$[\text{Reduced Transit Fleet Operating Costs}]_{\text{Year}} = [\text{operating cost per mile}]_{\text{Year}} \times [\text{annual non-revenue vehicle miles}]_{\text{Year}} \times [\text{\% savings in transit (non-revenue) vehicle miles}].$$

where:

[operating cost per mile]$_{Year}$	Represents the transit agency's vehicle operating cost per vehicle mile (includes only costs of fleet operations). For OS/CAD operational deployments, it reflects the projected fleet operating cost per mile in year 2000. For deployments under implementation or planned, it reflects projected fleet operating costs per mile in years 2003 and 2005, respectively.
[annual non-revenue vehicle miles]$_{Year}$	Represents the transit agency's projected annual non-revenue vehicle miles[15] in years 2000, 2003 and 2005, for OS/CAD deployments that are operational, under implementation, and planned, respectively.
[% savings in transit (non-revenue) vehicle miles].	Represents the assumed reduction in transit (non-revenue) vehicle miles resulting from the implementation and operation of operating software and computer-aided dispatch systems. The percentage savings is based on a probability distribution based on minimum, most likely and maximum values.
Year	Represents year 2000 for OS/CAD operational deployments, year 2003 for deployments under implementation, and year 2005 for OS/CAD planned deployments.

This analysis projected that the total benefits, over the next ten years, for the APTS automated operational software and computer-aided dispatch system deployments would range from $502.3 million (minimum estimate) to as high as $853.3 million (maximum estimate). The projected most likely estimate of the total OS/CAD benefits is $675.5 million. These benefits are expressed in discounted, year 2000 present value dollars.

Table 5-3 and Figure 5-3 present the projected minimum, most likely and maximum benefits (in discounted, year-2000 dollars) for OS/CAD system deployments that are currently operational, under implementation and planned for deployment.

Table 5-3. Operating Software and Computer-Aided Dispatch Benefits (in Millions of discounted Y2000 dollars)

	Number OS/CAD Deployments	OS/CAD Benefits Minimum Estimate	OS/CAD Benefits Most Likely Estimate	OS/CAD Benefits Maximum Estimate
Operational	126	$360.5	$478.1	$594.3
Implementation	25	$52.8	$71.9	$92.8
Planned	72	$88.9	$125.4	$166.3
Total	223	$502.3	$675.5	$853.3

[15] An agency's annual non-revenue vehicle miles represents the difference in the total annual vehicle miles operated and the annual vehicle miles operated in revenue service for a given mode of transit operation.

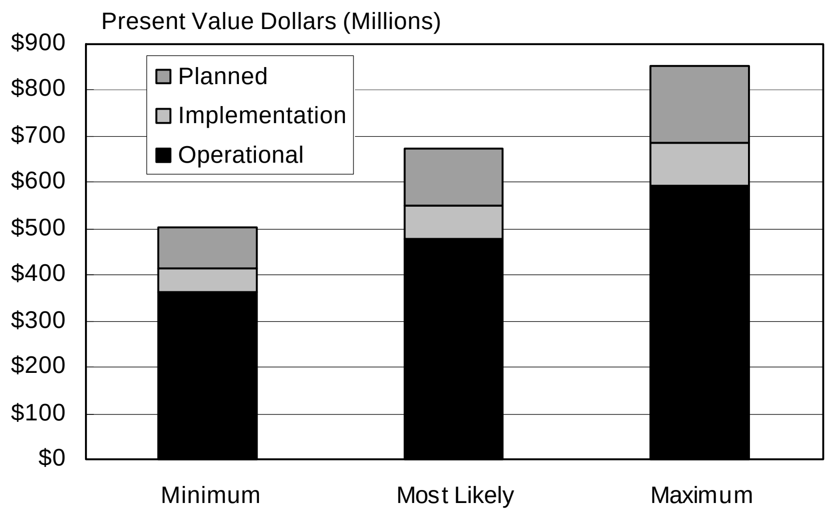
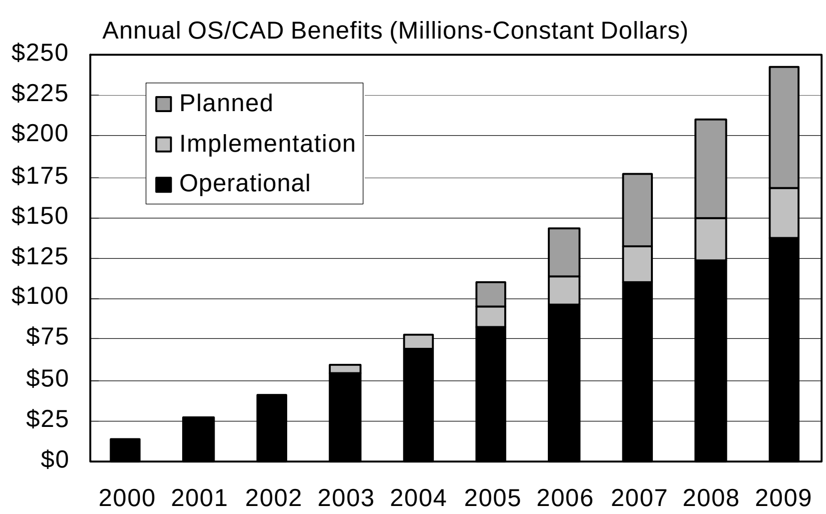


Figure 5-3. OS/CAD Benefits

Over 70% of the total projected benefits for the OS/CAD systems are derived as a result of the currently operational deployments. OS/CAD deployments that are currently under implementation and planned represent 11% and 18%, respectively, of the total benefits.

Figure 5-4 illustrates the distribution of the projected annual benefits, over the ten year analysis period, for the most likely OS/CAD benefits estimate. The annualized benefits reflected in this figure are expressed in millions of constant, year 2000 dollars.



Annual OS/CAD Benefits
(Millions Constant Dollars)

Year	Benefits
2000	$14
2001	$28
2002	$41
2003	$59
2004	$78
2005	$111
2006	$144
2007	$177
2008	$210
2009	$243
Total	$1,104

Figure 5-4. Annual OS/CAD Benefits

A summary of the projected minimum, most likely and maximum OS/CAD system benefits in constant and discounted, year 2000 dollars is presented in Table 5-4. This table also identifies the distribution of the OS/CAD system benefits, by transit mode and by phase of deployment (operational, under implementation and planned). Over 66% of the OS/CAD system benefits are accrued by transit fixed-route bus deployments. Commuter rail and demand responsive transit deployments represent 22% and 8%, respectively, of the total benefits. Projected deployments for heavy rail and light rail operations represent less than 5% of the total OS/CAD benefits.

5.3 Operational Software and Computer Aided Dispatching System Costs

The costs of transit operational software and computer-aided dispatching systems vary, depending on the transit mode and the features usually incorporated with each system application. For fixed-route bus systems, the costs of operational software are usually incorporated as part of AVM/AVL fleet management and dispatching systems. Future applications of these systems are being focused on the use of expert systems, using AVM/AVL data for service planning, passenger itinerary planning, and real-time control of fixed-route bus operations. For rail operations, operational software systems are usually integral to a rail communications-based train control system and are often included as part a transit system's central rail dispatch and control center operations. The availability of accurate cost information for rail operational software is limited and/or not readily identifiable as part of the costs of transit rail dispatch and control systems.

The costs of demand-responsive operational software and computerized dispatching systems also varies by the type of application and the types of features offered. The most recent APTS State of the Art report, Update 2000 [Ref. 14], indicates that the market for DRT-CAD are often constrained by the availability of reliable systems and qualified vendors. While there are over 5,000 demand responsive systems in operation in the United States, the market for DRT-CAD is very small, with only around 100 systems implemented each year. Other issues that impact the deployment of DRT-CAD systems include: the lack of industry standards for these systems, implementation and training issues, and the availability of qualified transit dispatchers to operate these systems. The recent report [Ref.17] on the application of operational software and computer-aided dispatch systems, within small urban and rural transit systems, summarizes the results of many DRT-CAD applications and presents key guidelines and issues to be considered in the implementation of these systems. Costs of demand-responsive operational software and computer aided dispatching systems can range from as low as $10,000 to in excess of $50,000 per system implementation. Low-end systems generally include basic report writing, schedule manifests and limited accounting information. Higher-end DRT software systems usually incorporate more advanced features, including fully automated capabilities for passenger registration, real-time and batch scheduling of trips, system interfaces with geo-coded mapping systems, AVL/AVM systems, and mobile digital messaging systems.

Table 5-5 presents a summary of operational software and computer-aided dispatching system costs for various fixed-route bus and demand responsive transit operations. The source of this information was the most recent Volpe survey [Ref. 5] on the application of APTS technologies within the transit industry.

Table 5-4. Operational Software and Computer-Aided Dispatching System Benefits

Minimum Estimate	Constant Year 2000 Dollars (Millions)				Discounted Present Value Dollars (Millions)			
	Operational	Implementation	Planned	Total	Operational	Implementation	Planned	Total
Fixed Route Bus	$324.0	$86.4	$130.8	$541.3	$204.7	$50.7	$73.0	$328.4
Demand Responsive	$54.7	$2.3	$4.0	$60.9	$34.5	$1.3	$2.2	$38.1
Commuter Rail	$180.3	$0.0	$0.2	$180.5	$113.9	$0.0	$0.1	$114.0
Heavy Rail	$11.3	$0.0	$23.2	$34.5	$7.1	$0.0	$13.0	$20.1
Light Rail	$0.6	$1.4	$1.0	$3.0	$0.4	$0.8	$0.6	$1.8
Total	$570.8	$90.1	$159.2	$820.1	$360.5	$52.8	$88.9	$502.3
Most Likely Estimate	Constant Year 2000 Dollars (Millions)				Discounted Present Value Dollars (Millions)			
	Operational	Implementation	Planned	Total	Operational	Implementation	Planned	Total
Fixed Route Bus	$429.7	$117.7	$184.6	$732.1	$271.4	$69.0	$103.1	$443.5
Demand Responsive	$72.5	$3.1	$5.4	$81.0	$45.8	$1.8	$3.0	$50.6
Commuter Rail	$239.1	$0.0	$0.3	$239.4	$151.0	$0.0	$0.2	$151.2
Heavy Rail	$15.0	$0.0	$32.8	$47.7	$9.4	$0.0	$18.3	$27.7
Light Rail	$0.8	$1.9	$1.5	$4.1	$0.5	$1.1	$0.8	$2.4
Total	$757.0	$122.7	$224.6	$1,104.3	$478.1	$71.9	$125.4	$675.5
Maximum Estimate	Constant Year 2000 Dollars (Millions)				Discounted Present Value Dollars (Millions)			
	Operational	Implementation	Planned	Total	Operational	Implementation	Planned	Total
Fixed Route Bus	$534.1	$151.9	$245.1	$931.1	$337.4	$89.0	$136.8	$563.2
Demand Responsive	$90.1	$3.9	$6.9	$100.9	$56.9	$2.3	$3.9	$63.1
Commuter Rail	$297.1	$0.0	$0.4	$297.5	$187.7	$0.0	$0.2	$187.9
Heavy Rail	$18.6	$0.0	$43.5	$62.1	$11.7	$0.0	$24.3	$36.0
Light Rail	$0.9	$2.4	$1.9	$5.3	$0.6	$1.4	$1.1	$3.1
Total	$940.9	$158.3	$297.8	$1,397.0	$594.3	$92.8	$166.3	$853.3

Table 5-5. Operational Software and Computer-Aided Dispatch System Costs

State	Transit System	Fleet Size MB	Fleet Size DRT	AOS	CAD	System Cost	Notes
AK	Municipality of Anchorage		31		✓	$90.0 K	
AL	Gadsden-Dial-A-Ride		11		✓	$15-$20 K	
AL	Montgomery-MAT		8		✓	$40.0 K	
AZ	Peoria Transit		11		✓	$50.0 K	Initial set-up costs.
AZ	Phoenix-Glendale		15		✓	$50.0 K	
AZ	Phoenix-RPTA	75		✓			In AVL costs. Central reservations and dispatch
CA	Bakersfield-GET		9		✓	$40.0 K	Phase II costs to upgrade software
CA	Contra Costa-Connection		40		✓	$120.0 K	
CA	Contra Costa-WESTCAT		11		✓	$60.0 K	
CA	Fresno-FAX		21		✓	$30.0 K	Upgrading to latest version of Trapeze
CA	LA-Access		243		✓	$300.0 K	
CA	LA-Long Beach Transit	199		✓		$300.0 K	
CA	Modesto-MAX	35	11	✓	✓	$50.0 K	
CA	Oakland-AC Transit	694		✓			Included in AVL system. $14.5 million for AVL.
CA	Riverside Special Trans.		19		✓	$40.0 K	
CA	Riverside-RTA		36		✓	$600.0 K	
CA	San Bernardino-OMNITRANS	137	88	✓	✓	$246.0 K	DRT costs only
CA	San Diego-NCTD	154		✓		$870.0 K	Upgrade 1999 to replace the dispatch control HW/SW
CA	San Joaquin-Smart	95	36	✓	✓	$800.0 K	
CA	Santa Clara – Outreach		155		✓	$800.0 K	
CA	SF-SamTrans	315		✓			Part of $9.5mil AVL system.
CO	Denver-RTD	849	540	✓	✓		Part of $12 million AVL project.
CO	Greeley-The Bus		5		✓	$15-$20 K	
CT	Hartford-Metro		136		✓	$100.0 K	
CT	Gr. New Haven		70		✓	$60.0 K	
DE	Delaware-DTC	186	109	✓	✓		Part of $5.5 M communications/AVL system
FL	Bradenton-MCT	16	18	✓	✓	$25K - $50K	Approximate cost
FL	Gainesville-RTS	47		✓		$100.0 K	
FL	Jacksonville-JTA	188		✓		$150.0 K	Approximate cost
FL	Tampa-Hartline	189		✓			Part of $1.6 M AVL system
GA	Augusta-APT	30		✓		$150.0 K	$130,000 software and $20,000 hardware.
HI	Honolulu-DTS		114		✓	$600.0 K	
IA	Des Moines-Metro	93		✓		$220.0 K	
IA	Dubuque, IA-KeyLine	18	6	✓	✓	$100.0 K	
IA	Five Seasons Trans	40	33	✓	✓	$35.0 K	
IA	Iowa City-CAMBUS		4		✓	$30.0 K	
IA	Sioux City-STC	36	26	✓	✓	$154.0 K	
IA	Waterloo-MET		25		✓	$80.0 K	
IL	Chicago-RTA-CTA	1,882		✓			Component of $33M AVL system
IL	Peoria-GP Transit		10		✓	$100.0 K	
IL	Rockford-RMTD		18		✓	$100.0 K	
KS	Johnson County Transit		40		✓	$20.0 K	Approximate cost
MA	Attleboro-GATRA		47		✓	$25.0 K	
MD	Montgomery County DPW&T	230		✓	✓		Part of $5.0M CAD/AVL system installed on 130 buses.
MI	Ann Arbor-AATA	69	47	✓	✓		Part of $2M AVL system.
MI	Bay City-Metro Transit		23		✓	$100.0 K	
MI	Detroit-SMART	300	150	✓	✓		Part of AVL system.
MN	St. Cloud-Metro Bus	28	22	✓	✓	$200.0 K	DRT component =$150,000; FR component =$50,000
MO	Springfield-CU		5		✓	$40.0 K	
NC	Greensboro-GTA		19		✓	$54.0 K	Approximate cost
NE	Omaha-TA	139		✓		$300.0 K	
NH	Portsmouth-COAST		1		✓	$80.0 K	Approximately $80,000 for software and network hardware
NM	Albuquerque-Sun Tran		43		✓		Included in $600K AVL costs.
NM	Santa Fe Trails		29		✓	$30.0 K	
NY	Broome County		23		✓	$24.0 K	
NY	NY-Hauppage-Suffolk Trans	164	26	✓	✓	$200.0 K	Integrated with AVL.
NY	NY-MTA-Long Island Bus	318		✓		$300.0 K	For DRT software.
NY	Poughkeepsie-LOOP		22		✓	$25.0 K	
NY	Rochester-RTS		25		✓	$137.0 K	Part of new radio system.
OH	Cleveland-LAKETRAN		64		✓	$57.7 K	
OK	Oklahoma City-COTPA		65		✓	$64.0 K	
OK	Tulsa-MTA		198		✓	$300.0 K	
PR	San Juan-MBA	250	27	✓	✓	$500.0 K	Fixed route component
RI	Providence-RIPTA		30		✓	$100.0 K	Hardware = $57,000; Software = $35,000
SC	Charleston-DASH		11		✓	$50.0 K	
SD	Sioux Falls-The Bus		58		✓	$56.0 K	
TN	Johnson City-JCT	10		✓		$45.0 K	
TX	Dallas-DART	543		✓			Part of $12M AVL system
TX	Dallas-Mesquite		13		✓	$45.0 K	
TX	Lubbock-Citibus		13		✓	$75K - $100K	Approximate cost
WA	Bellingham-WTA		61		✓	$423.0 K	
WI	Madison-MMT	188	92	✓	✓	$200.0 K	Cost covers DRT schedule, FR schedule, dispatch system.

Legend: AOS - Automated Operational Software; CAD - Computer Aided Dispatch
Source: APTS 1999 Deployment Survey Data; Volpe Center

Section 6
Electronic Fare Payment Systems

The use of cash in transit fare payment has long been seen as a problem for both transit riders and transit operators. Cash fares can be inconvenient for the rider and the need for exact fare can be a barrier to the use of transit. In cities with multiple transit operators, exact fares must often be paid for each leg of the trip, and transfers between buses or trains operated by different agencies are generally difficult or nonexistent. Operationally, it is expensive to administer the collection of cash fares. For every dollar a transit agency receives in passenger revenue, it spends approximately six cents on fare collection and processing. Most of the cost is associated with collecting, transporting, counting and guarding cash. Dollar bill processing is particularly difficult and costly. Reducing the use of cash for fare payment provides a clear benefit for transit operators. [Ref. 18].

Today, many transit agencies are looking at ways to improve their fare collection to meet a number of objectives. Primary among these are: eliminating cash and token handling to improve security of transit fares, introducing more innovative and equitable fare structures; providing increased convenience to transit riders in the purchase and payment of transit fares; and reducing overall transit costs of sorting, counting, and management of fare revenues.

Advanced electronic fare payment systems include a wide-range of automated fare collection system technologies and advanced fare media that make fare payment more convenient for the transit user and financial management of fare revenues more secure and efficient for the transportation provider. Electronic fare payment technologies are now capable of handling a variety of fare media including coins, bills, magnetic strip paper or plastic cards, and integrated circuit or radio frequency smart cards. Advances in fare media in recent years have been moving towards applications with stored value smart cards and credit cards issued by banks and other financial institutions.

Advanced fare payment systems date back to the 1970s with initial applications of magnetic strip, stored value fare cards in rail transit systems in San Francisco-Oakland (BART) and Washington, DC (WMATA) and with the installation of magnetic card readers on electronic fare boxes at Phoenix Transit in 1991 [Ref. 19]. In recent years, advances in electronic fare payment media have increased the number of applications of electronic, stored-value fare cards and various pre-paid, multiple-use fare payment arrangements between transit agencies and other private/public agencies and institutions (i.e., financial, retail, commercial companies, universities, and other governmental and social service agencies). Most notable of the more recent transit electronic fare payment and multipurpose fare payment applications include:

- *MARTA/VISA VisaCash Program* - In 1995, the Metropolitan Atlanta Rapid Transit Authority (MARTA) partnered with Visa and three local banks to offer a VisaCash stored value, contact card in time for the 1996 Summer Olympic games. The VisaCash program was initiated as a demonstration project, and involved a total of 4,200 terminals installed at bank, merchant locations and MARTA bus/rail stations.

One of the key outcomes of the demonstration project is that it identified a number of implementation issues associated with this technology and other issues associated with the feasibility of establishing such a program with financial institutions[16]. In 1997, following the initial demonstration of the VisaCash program, MARTA entered into a one-year extension of the program for further evaluation. MARTA is also conducting a comprehensive fare collection study, that would consider such issues as open vs. closed fare payment systems, disposable vs. reloadable cards, contact vs. contactless cards, and alternative fare card financing approaches [Ref. 18].

- *Central Puget Sound Regional Fare integration Project (CPSFIP)* - In April1994, the transportation agencies throughout the Central Puget sound area created a regional fare collection project to evaluate the potential implementation of smart card fare technology among the various interrelated transportation systems in the region. Participants included: Community Transit, Everett Transit, King County Metro, Kitsap Transit, Pierce Transit and the Washington State Ferry System. Overall reactions from both customer surveys and regional focus groups on the demonstration program were positive. In July 1996, following the initial demonstration period, King County issued a Request for Proposal for the design, development and implementation of a coordinated regional fare collection system incorporating smart card technology. Implementation of this program is expected to cost $10.5 million, depending on the actual equipment chosen and other implementation issues. The feasibility study of this program concluded that the smart-card program would generate a 20% increase in the number of employer passes sold, resulting in an annual revenue increase of $450,000 to $750,000. The study also estimated savings, through reduced fraudulent pass use and fare evasion, ranging from $120,000 to $180,000 per year. In addition, the study estimated additional revenues to the transit authorities from $43,000 to $65,000 per year on the annual float[17] on the use of the smart cards [Ref. 18].
- *WMATA Metro SmarTrip Project* - In December 1994, the Washington Metropolitan Area Transit Authority (WMATA) began testing the feasibility of a contactless card (then called the Go-Card) for use on its bus, rail and park-and-ride facilities. Under the initial evaluation, Go-Card readers were installed in 24 rail stations, on twenty-one buses operating on three routes, and five park-ride facilities. The results of the initial demonstration has led WMATA to proceed with the application of the smart-card technology (SmarTrip) on its entire rail system and park-and-ride lots. Long term plans call for the development of a totally integrated fare collection system that allows WMATA patrons to use one fare media on all transit systems in the Washington, DC metropolitan area. [Ref. 18].

Other applications of advanced fare payment technologies (or the initiation of feasibility studies on the use of these technologies) are currently underway in Ventura County, CA (smart card program); San Francisco Bay Area, CA (TransLink Program); Phoenix, AZ (credit card program); Ann Arbor, MI (smart card); Wilmington, DE (smart-card); New York City Metropolitan

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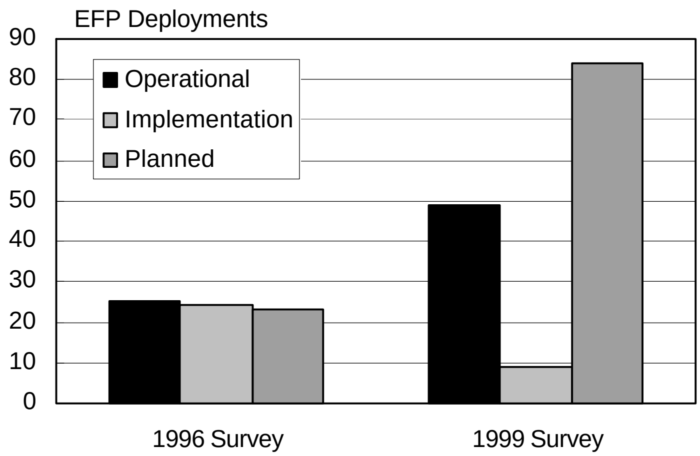
[16] The TCRP Report 32 [Ref. 18] provides a more detailed discussion of the MARTA VisaCash demonstration program and a summary of the major results and issues that were identified with this program.

[17] Float is the potential income that a transit agency derives though the use of pre-paid monies on stored-value and debit cards. Depending on the size of application and the number of cards outstanding, the value of potential income can be quite significant.

Transit Authority (Metro Card); and the Greater Cleveland Regional Transit Authority (GCRTA), OH (multi-use smart card).

6.1 Electronic Fare Payment System Deployments

Over the past five years, there has been a significant increase in the number of deployments of Electronic Fare Payment (EFP) systems and in the number of transit systems implementing or planning the implementation of these systems. Figure 6-1 illustrates the growth in the number of electronic fare payment system deployments, based on the results of two recent surveys [Refs. 4, 5] conducted by the Volpe Center of the transit industry. As shown, the number of EFP system deployments (currently operational, under implementation, and planned) has nearly doubled over the past five years, with the largest increases in the number of deployments that are currently operational (96% increase) and those that are being planned (265% increase).



Electronic Fare Payment Deployments

	1996 Survey	1999 Survey
Operational	25	49
Implementation	24	9
Planned	23	84
Total	72	142

Figure 6-1. Growth in Electronic Fare Payment Deployments

Of the total electronic fare payment system deployments that were identified in the most recent survey, 40% of the transit system deployments of EFP systems are using or are planning to use smart card technology and 35% of the system deployments are using or planning to use magnetic stripe cards (Figure 6-2). The application of credit card and debit card technologies represent 7% and 4%, respectively, of all deployments (operational, under implementation and planned), while approximately 14% of the deployments have not identified the type of EFP technology that will be implemented. A survey, within the TCRP Report 32 [Ref.19], of transit

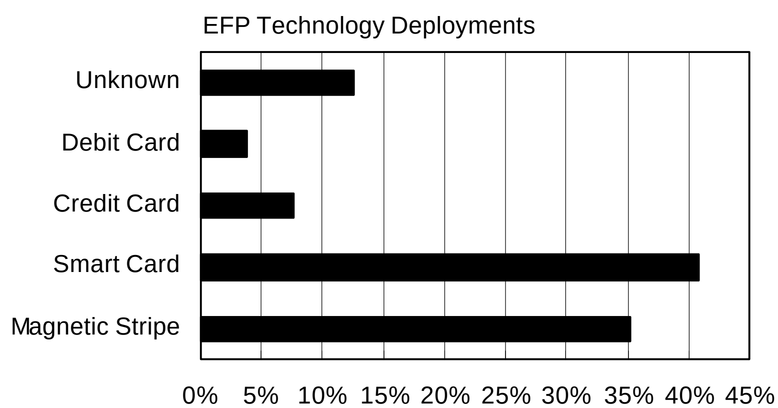
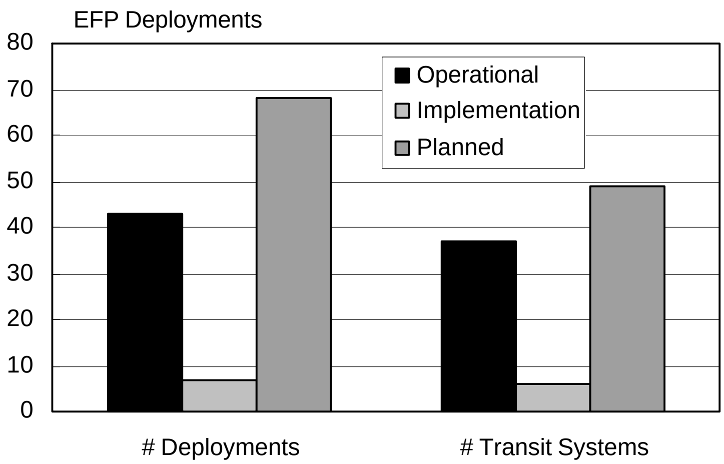


Figure 6-2. EFP Technology Deployments

agencies and transit users cited a number of reasons for the increasing trend in the use of stored-value media for transit fare payment. Transit riders place a high value on the convenience of purchasing and using stored value cards, especially whenever financial incentives, such as high-use discounts are offered with these cards. For transit agencies, the benefits of adopting stored-value fare payment systems include: improved flexibility in the establishment of fare policies and fare structures, reduced fare collection costs, expanded market base, improved customer convenience, and increased revenues (as a result of the use of the available money float, expired card values, and reduced fare evasion).

As a basis for estimating the current and projected electronic fare payment system benefits, this analysis considered a total of 118 deployments of EFP systems that are currently operational, under implementation or planned over the next five years. Figure 6-3 shows the stratification of the electronic fare payment system deployments and the corresponding number of transit systems that have EFP systems operational, under implementation, and planned. Of the total 118 deployments considered over the 92 transit agencies, 36% are currently operational, 6% are under implementation, and the remaining 58% are planned for deployment.



EFP System Deployments

	Number of Deployments	Number of Transit Systems
Operational	43	37
Implementation	7	6
Planned	68	49
Total	118	92

Figure 6-3. EFP Deployments Considered in the Analysis

A breakdown of these deployments by transit mode, along with the corresponding size of the transit vehicle fleet, is presented in Table 6-1.

Table 6-1. Electronic Fare Payment System Deployments Considered in the Analysis

	Operational		Under Implementation		Planned		Total	
Mode	Number of Deployments	Fleet Size	Number of Deployments	Fleet Size	Number of Deployments	Fleet Size	Number of Deployments	Fleet Size
FRB	27	9,458	5	392	43	8,977	75	18,827
DRT	5	67	2	113	17	655	24	835
CR	4	1,313	0	0	2	973	6	2,286
HR	7	8,899	0	0	2	89	9	8,988
LR	0	0	0	0	4	186	4	186
Total	43	19,737	7	505	68	10,880	118	31,122

FRB = Fixed Route Bus, DRT = Demand Responsive Transit, CR = Commuter Rail, HR = High Speed Rail, LR = Light Rail

A listing of the electronic fare payment system deployments (operational, under implementation, and planned) considered in this analysis is presented within Appendix B of this report.

6.2 Electronic Fare Payment System Benefits

The primary benefits cited by transit agencies with the deployment of electronic fare payment systems include:

- *Improved security of transit revenues*. The introduction of advanced fare collection technologies and fare media reduces the amount of lost revenues due to fare evasion. Within the transit industry, estimates of lost revenues due to fare evasions range from 4% to 8% [Ref. 20]. In the survey conducted in conjunction with the TCRP Report 32 [Ref. 18], transit respondents estimated that the average amount of revenue lost through theft, fraud and counterfeiting was approximately 1%, or an average of $1 million per year. This amount was significantly larger (1.6%) for larger transit systems, resulting in annual losses in revenues of approximately $1.8 million. In 1993, when the New York City Transit Authority installed a magnetic strip system, the transit authority realized an additional revenue capture of $43 million and in 1994, an additional $54 million as a result of tightened revenue security measures and savings from reduced fare evasions. The reduction in fare evasions went from 4% to under 2% [Ref. 21].
- *Increased transit ridership and convenience*. Electronic fare payment systems improve customer convenience in the payment of transit fares and by providing a wider range of services. Electronic fare payment systems facilitate the integration of fares across regional transportation services (transit and non-transit), through a single payment media. The need for tokens, cash (exact change) and transfer slips is reduced, as well as the frequency of advanced purchases of transit fares. Electronic fare payment systems also encourage increased flexibility in fare policies (time and/or distance based fares) to promote off-peak ridership or ridership by targeted market groups (e.g., employer subsidized fares for commuters, subsidized fares for the disadvantaged, etc.). The Chicago Transit Authority (CTA) found that the use of stored-value cards and inter-modal transfers increased transit ridership. Estimates from their applications showed that stored-value cards and the inter-modal transfers under an integrated fare system increased transit ridership by 2% to 5% [Ref. 22].
- *Expanded base for transit revenue*. Electronic fare payment systems provide a base of expanded revenue to transit agencies though increased marketing opportunities, interest or “float” earned on prepaid fares, transaction fees, and unused value on prepaid, stored value cards. From business case studies conducted for the New York City Transit, the MTA estimates [Ref. 9] that their MetroCard system will generate increased revenues of $34.0 million from merchant fees and revenue float, $140.0 million from unused prepaid, stored value cards, and $49.0 million in revenues from new transit ridership as a result of expanded marketing opportunities. As part of the Central Puget Sound Smart-Card study, it was estimated that additional revenues of approximately $43,000 to $65,000 annually would be derived through interest or ‘float’ on pre-paid fares [Ref.18].

- *Reduced fare collection/processing costs*. Costs of handling cash and token fares are a major cost of a transit system's operating budget. Applications of electronic fare payment systems reduce agency costs in the counting and handling of cash, tokens, and transfers and, in some cases, enable these functions to be borne by banks, credit card companies, or other financial management institutions. New Jersey Transit estimates cost savings of up to $2.7 million in reduced labor costs of handling cash and tokens [Ref. 9]. Ventura County estimates that their smart card system will save the agency $9.5 million in reduced fare evasion, $5 million in reduced data collection costs, and $990,000 in reduced costs of handling fares and transfer slips [Ref. 9].
- *More equitable, flexible fare structures*. Advanced fare media allow transit agencies to adopt more flexible and equitable distance based fare structures, that facilitate coordinated transportation services and inter-modal transfers. These fare structures would increase overall transit ridership and transit revenues. In the Los Angeles area, multi-operator fare agreements are increasing the use of mass transit, reducing traffic congestion, and increasing transit productivity. In 1993, the Los Angeles region began testing both smart card (chip embedded) and debit card (magnetic strip) technologies to integrate fare payment. As a result of increased service and fare coordination, inter-operator transfers, which accounted for less than 0.5% of all riders in 1988, had increased to at least 2% of total passengers, or 11 million transit passenger trips per year by 1994 [Ref. 23].

This analysis assumed that the primary benefits associated with the deployment of electronic fare payment systems would be accrued by transit agencies in the form of increased transit ridership and savings in passenger fare revenues. These benefits represent increased revenues to transit agencies, based on annual recurring savings in passenger fare revenues and/or reductions in the costs of handling and processing transit fares. Estimated EFP system deployment benefits (minimum, most likely, and maximum) were developed based on the following assumed variables (Table 6-2) and equation outlined below.

Table 6-2. Electronic Fare Payment Analysis Assumptions

Variable	For the period 1997-2000	Minimum Estimate	Most Likely Estimate	Maximum Estimate
% annual increase in: • transit ridership	1.0%	1.0%	2.0%	3.0%
• transit fares	n/a	1.0%	2.0%	3.0%
% savings in transit fare revenues		1.0%	2.0%	3.0%

$$[\text{Transit fare revenue savings}]_{\text{Year}} = [\text{Projected annual passenger trips}]_{\text{Year}} \times [\text{average fare per passenger trip}]_{\text{Year}} \times [\%\ \text{savings in transit fare revenues}].$$

where:

[Projected annual passenger trips]$_{\text{Year}}$	Represents the transit agency's projected annual passenger trips. For EFP operational deployments, it reflects the projected annual passenger trips in year 2000. For deployments under implementation or planned, it reflects the projected annual passenger trips in years 2003 and 2005, respectively.

[average fare per passenger trip]$_{Year}$	Represents the transit agency's projected average fare per passenger trip in years 2000, 2003 and 2005, for EFP deployments that are operational, under implementation, and planned, respectively.
[% savings in transit fare revenues].	Represents the assumed savings in transit fare revenues resulting from the implementation and operation of electronic fare payment systems. The percentage savings is based on a probability distribution based on minimum, most likely and maximum values.
Year	Represents year 2000 for EFP operational deployments, year 2003 for deployments under implementation, and year 2005 for planned EFP system deployments.

This analysis projected that the total benefits, over the next ten years, for the electronic fare payment system deployments would range from $1.2 billion (minimum estimate) to as high as $3.5 billion (maximum estimate). The projected most likely estimate of the total electronic fare payment system benefits is $2.3 billion. These benefits are expressed in discounted, year 2000 present value dollars.

Figure 6-4 and Table 6-3 present the projected minimum, most likely and maximum benefits (in discounted, year-2000 dollars) for electronic fare payment systems that are currently operational, under implementation and planned for deployment.

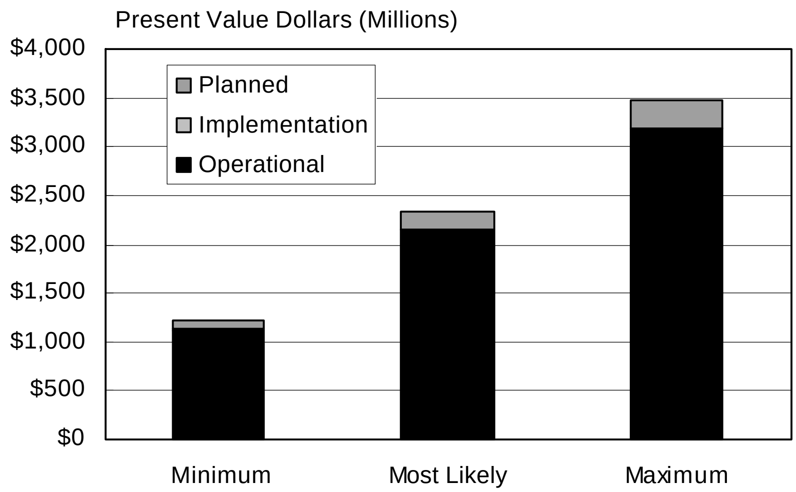


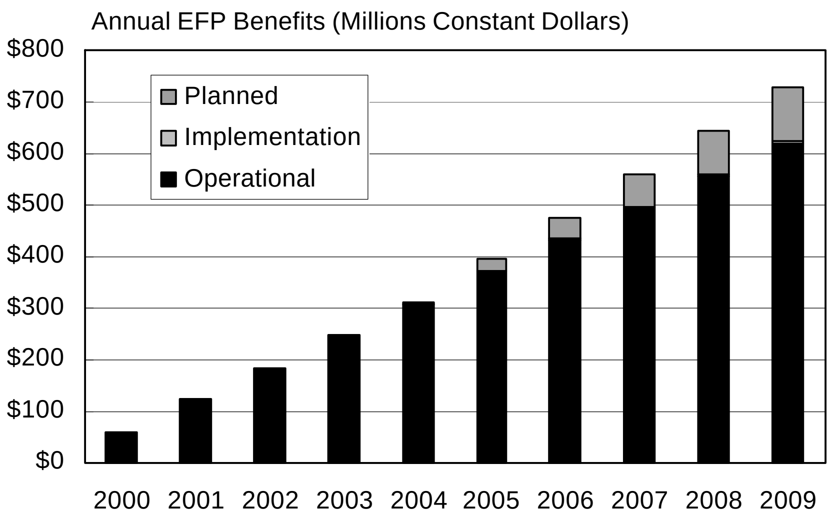
Figure 6-4. Electronic Fare Payment System Benefits

Table 6-3. Electronic Fare Payment Benefits (in Millions of discounted Y2000 dollars)

	# EFP Deployments	EFP Benefits Minimum Estimate	EFP Benefits Most Likely Estimate	EFP Benefits Maximum Estimate
Operational	43	$1,123.1	$2,150.3	$3,182.0
Implementation	7	$4.0	$7.7	$11.5
Planned	68	$91.6	$178.2	$271.4
Total	118	$1,218.7	$2,336.1	$3,464.9

Over 92% of the total projected benefits for the electronic fare payment systems are derived from currently operational EFP system deployments. Electronic fare payment system deployments that are currently under implementation and planned represent less than 1% and 7%, respectively, of the total benefits.

Figure 6-5 illustrates the distribution of the projected annual benefits, over the ten year analysis period, for the most likely electronic fare payment benefits estimate. The annualized benefits reflected in this figure are expressed in millions of constant, year 2000 dollars.



Total Annual EFP Benefits
(Millions Constant Dollars)

Year	Benefits
2000	$62
2001	$124
2002	$186
2003	$248
2004	$310
2005	$394
2006	$478
2007	$561
2008	$645
2009	$729
Total	$3,737

Figure 6-5. Annual EFP System Benefits

A summary of the projected minimum, most likely and maximum electronic fare payment system benefits, in constant and discounted, year 2000 dollars is presented in Table 6-4. This table also identifies the distribution of the EFP benefits, by transit mode and by phase of deployment (operational, under implementation and planned). This analysis projects that nearly 58% of the total electronic fare payment benefits over the next ten years will be accrued by transit high-speed rail deployments. Operational and projected deployments of electronic fare payment systems on fixed-route bus systems represent 38% of the total EFP benefits. Commuter rail, light rail and demand responsive deployments of electronic fare payment systems are expected to accrue less than 4% of the total EFP benefits.

Table 6-4. Summary of Projected Electronic Fare Payment System Benefits

Minimum Estimate	Constant Year 2000 Dollars (Millions)				Discounted Present Value Dollars (Millions)			
	Operational	Implementation	Planned	Total	Operational	Implementation	Planned	Total
Fixed Route Bus	$609.1	$6.7	$141.0	$756.7	$384.7	$3.9	$78.7	$467.3
Demand Responsive	$0.2	$0.1	$0.4	$0.7	$0.1	$0.0	$0.2	$0.4
Commuter Rail	$54.1	$0.0	$12.4	$66.5	$34.2	$0.0	$6.9	$41.1
Heavy Rail	$1,114.9	$0.0	$3.4	$1,118.2	$704.2	$0.0	$1.9	$706.0
Light Rail	$0.0	$0.0	$6.8	$6.8	$0.0	$0.0	$3.8	$3.8
Total	$1,778.2	$6.8	$164.0	$1,948.9	$1,123.1	$4.0	$91.6	$1,218.7
Most Likely Estimate	Constant Year 2000 Dollars (Millions)				Discounted Present Value Dollars (Millions)			
	Operational	Implementation	Planned	Total	Operational	Implementation	Planned	Total
Fixed Route Bus	$1,166.1	$12.9	$274.4	$1,453.4	$736.5	$7.6	$153.2	$897.3
Demand Responsive	$0.3	$0.2	$0.8	$1.3	$0.2	$0.1	$0.4	$0.7
Commuter Rail	$103.5	$0.0	$24.1	$127.7	$65.4	$0.0	$13.5	$78.9
Heavy Rail	$2,134.4	$0.0	$6.6	$2,141.0	$1,348.1	$0.0	$3.7	$1,351.8
Light Rail	$0.0	$0.0	$13.3	$13.3	$0.0	$0.0	$7.4	$7.4
Total	$3,404.4	$13.1	$319.1	$3,736.5	$2,150.3	$7.7	$178.2	$2,336.1
Maximum Estimate	Constant Year 2000 Dollars (Millions)				Discounted Present Value Dollars (Millions)			
	Operational	Implementation	Planned	Total	Operational	Implementation	Planned	Total
Fixed Route Bus	$1,725.6	$19.4	$417.9	$2,162.9	$1,089.9	$11.4	$233.3	$1,334.6
Demand Responsive	$0.5	$0.2	$1.2	$1.9	$0.3	$0.1	$0.7	$1.1
Commuter Rail	$153.2	$0.0	$36.7	$190.0	$96.8	$0.0	$20.5	$117.3
Heavy Rail	$3,158.5	$0.0	$10.0	$3,168.5	$1,995.0	$0.0	$5.6	$2,000.5
Light Rail	$0.0	$0.0	$20.2	$20.2	$0.0	$0.0	$11.3	$11.3
Total	$5,037.8	$19.7	$486.0	$5,543.4	$3,182.0	$11.5	$271.4	$3,464.9

6.3 Electronic Fare Payment System Costs

The costs associated with transit fare collection represents a significant portion of a transit agency's operating budget. The costs of transit fare collection can vary widely. Recent surveys conducted in conjunction with the TCRP studies on transit fare systems [Refs. 18, 24] found that some agencies spend less than 1% of their total fare revenue on fare collection and related costs, while other agencies spend as much as 20% of all farebox revenue on fare collection and processing. The average for all agencies (responding to the survey) was roughly 6% of all fare revenues collected.

Comprehensive analyses on the costs associated with the implementation and advanced fare collection technologies and multipurpose fare payment systems are available as part of the Central Puget Sound Regional Fare Study [Ref. 25] and the San Francisco Bay Area TransLink programs [Ref. 26]. The Central Puget Sound Regional Fare study examined the cost impacts to the King County Metro system and found that the estimated costs of a smart card system, compared to existing Metro fare collections costs, would range from an increase in costs of approximately $139,000 per year (4% of annual fare processing costs) to a savings of approximately $309,000 (more than 9% of current fare collection/processing costs). The study estimated that the overall effect on Metro fare collection and processing costs would result in a savings of $495,000 to $804,000 per year with full system implementation [Ref. 18]. The San Francisco Bay Area TransLink study compared the costs associated with existing fare collection system with the estimated TransLInk implementation and operations costs. The study determined that TRANSLink would result in 4% lower fare collection and processing costs, compared to the existing systems, producing a savings of $1.5 million over the five-year analysis period [Ref. 18].

Table 6-5 presents a summary of representative advanced fare payment system costs. The source of this information was the most recent Volpe survey [Ref. 5] on the application of electronic fare payment technologies within the transit industry.

Table 6-5. Electronic Fare Payment System Costs

		Total Vehicle Fleet					Automated Fare	Multi-Fare		
State	Transit System	MB	DRT	CR	HR	LR	Payment	Integration	System Cost	Notes
AZ	Phoenix-Mesa SunRunner	23					MS, CC		unknown	
AZ	Phoenix-RPTA	53					CC		unknown	Magnetic stripe cards (1990); Master/Visa (1995).
CA	Contra Costa-WESTCAT	16	11				SC	✓	$85.0 M	for TRANSLINK
CA	LA-Foothill Transit	259					MS		$2.4 M	for entire system
CA	LA-OCTA	428	98				U	✓	$3.0K-5.0K per vehicle	under study
CA	LA-Santa Monica	135					MS	✓	$2.7 M	Regional fare payment system. Pre-payment capabilities.
CA	LA-Torrance	74					SC		$858.0 K	For Faretrans system
CA	San Bernardino-OMNITRANS	137					MS	✓	$2.0 M	Approximate cost
CA	San Diego-NCTD			21			CC		$1.8 M	Approximate cost
CA	San Francisco-BART				668		MS, SC		$80.0 M	Approx. cost for AFC modernization plan.
CA	San Joaquin-Smart	95	36				MS		$2.5 K per bus	Approximate cost; on about 112 buses.
CA	Santa Cruz-METRO	78					MS		$750.0 K	
CA	Ventura Intercity Service	12	6				SC		$6.0 K per vehicle	Part of SMARTCARD demonstration project.
CA	Ventura-Thousand Oaks	4					SC		unknown	Part of SMARTCARD demonstration project.
CA	Yolo County Transportation District	25					U	✓	$120.0 K	
CO	Denver-RTD	849				17	SC	✓	$10.0 M	Approximate cost
CT	New Britain Transit	11					MS		$55.0 K	
CT	Norwich South East Area Transit	25					MS		$2.5 M	for SEAT & Connecticut Transit
FL	Ft. Lauderdale-BCT	232					U		$1.5 M	under study
FL	Ft. Lauderdale-TCRA			34			CC		$6.6 M	
FL	Pensacola-ECTS	39					SC		$40.0 K	
FL	Port Richey Pasco Co. PTD	8					U		$150.0 K	Approximate cost; under study
FL	Tampa-Hartline	189					MS	✓	$200.0K - $250.0K	Approximate cost; under study
IA	Des Moines-Metro	93					MS, SC		$1.2 M	Approximate cost; under study
IA	Dubuque, IA-KeyLine	18	6				SC	✓	$15.0 K	for single fleet.
ID	Boise Urban Stages	37					U		$88.0 K	
IL	Chicago-RTA-CTA	1,882			1,150		MS		$75.0 M	
IL	Chicago-RTA-Pace	762					MS, SC		$6.5 M	RF card (1997); Stored Value card (1999)
IN	Evansville-METS	26					MS, SC		$212.0 K	
MA	Springfield-PVTA	41					MS		$1.5 M	Approximate cost
MA	Worcester-WRTA	52					MS		$500.0 K	includes fareboxes
MI	Ann Arbor-AATA	69					SC	✓	$50.0 K	
MN	Mankato Heartland Express	15					U	✓	$84.0 K	for 12 buses
NC	Charlotte-CTS	170	48				MS, SC		$2.0 M	
NY	NY-Hauppage-Suffolk Trans	164	26				MS		$1.1 M	includes upgrade to new fareboxes
NY	NY-MTA-Long Island RR			1,187			MS		$0.10/card	seamless transport
NY	NY-MTA-NYCTA	3,867			5,790		MS		$80.0 M	Approximate cost
NY	Syracuse-RTA-Centro	174	17				MS		$1.7 M	Approximate cost
OH	Cleveland-RTA				59	47	SC		$900.0 K	Demonstration (1999)
OK	Oklahoma City-COTPA		65				MS		$660.0 K	Approximate cost
OR	Eugene-LTD	97					SC		$0.5 - $1.0 M	Approximate cost
TN	Memphis-MATA	194					U		$2.6 M	Approximate cost; under study
TX	Fort Worth-The T	154	78				SC	✓	$2.5-$3.0 M	Approximate cost; under study
WA	Seattle-Everett	41					SC	✓	$500.0 K	Approximate cost; under study
WI	Milwaukee-Waukesha Metro	20					MS		$5.8 K per bus	deployment on 14 new buses
WV	Mid-Ohio Valley Transit	6					SC		$150.0 K	Approximate cost; under study

Legend: MS – Magnetic stripe card, SC - Smart Card; CC - Credit Card; U - Other / Unknown;

Source: APTS 1999 Deployment Survey Data; Volpe Center

Section 7
Advanced Traveler Information Systems

Advanced Traveler Information Systems (ATIS) are key technology applications within the transit industry, designed to provide timely and accurate information to help transit riders make decisions on modes of travel, routes, and travel times. There are many ways to characterize passenger information systems and, for most cases, these systems fall into one of the following four categories:

- *Itinerary planning systems*, which allow passengers to plan total (origin to destination) trips using one or more available transit services. These systems are directed to those transit passengers (e.g., tourists, visitors) who are making one-time trips or who are less familiar with available transportation services and destinations.
- *Static information systems,* which are pre-printed information on system and route maps, schedules, fares, transfer points and other transit promotions. In recent years, this information has been expanded to include information presented to travelers through telephone information systems, transit terminal information displays, and transit internet web sites.
- *Real-time information systems*, are geared to providing transit patrons with up-to-date information on scheduled transit vehicle arrival times, delays of routes, service disruptions and re-routings. Generally, this information is provided to transit riders through in-vehicle, wayside or terminal display systems, through automated telephone messaging systems, cable television, and through internet web sites. Current deployments in real-time transit information systems are generally made available through the integration of other APTS technologies such as AVL/AVM systems, freeway access and traffic signal systems, and centralized transportation traffic management centers.
- *Transit accessibility systems*, which are directed towards providing improved transit information to passengers with disabilities. These technologies exist in the form of "talking signs", "talking kiosks", telephone information systems, and in-vehicle annunciators.

Major deployments of advanced traveler information systems are currently in operation (or planned for implementation) include:

- Transit Watch, is a automated traveler information system being implemented as part of Seattle's Smart Trek Metropolitan Model Deployment Initiative (MMDI). This system provides enroute bus patrons with real-time bus arrival and departure information at three Seattle Metro transit centers. Transit Watch, which became operational in July, 1998 utilizes updated bus arrival times based on information from Metro's automatic vehicle location system. A companion transit information system, also implemented as part of Seattle's MMDI program, is BusView which provides transit patrons updated bus schedule and arrival information via the internet [Ref. 14].

- In Minneapolis, a Federally funded demonstration project, Travlink, was conducted (1994-1995) to improve the transit commute from the western suburbs of Minneapolis to the downtown area and to the University of Minnesota along a 11-mile corridor of Interstate 394. Travlink employed a computer-aided dispatch and automatic vehicle location (CAD/AVL) system[18] to provide real-time vehicle location information to a transit dispatch center and to an advanced traveler information system (ATIS). This system allowed dispatchers to monitor the progress and movement of buses and provided transit commuters with updated transit arrival times on electronic signs, display monitors, information kiosks, and through video-text terminals in homes and businesses. Results of the initial demonstration test, which was completed in December 1995, showed "that Travlink has been effective in its major objective, that of providing commuters with traveler information ... and by the end of the test, bus ridership among Travlink participants was six percent greater than that among the control group" [Ref. 27]. In a follow-up to the TravLink program, the Minnesota DOT initiated a two-year program, called ORION, as part of the Minnesota Guidestar ITS initiative. Within the Minnesota's DOT Metro division, ORION will expand on the TravLink efforts with $7.5 million for transit enhancements. ORION will equip over 290 Metro buses with AVL capabilities to improve on-time performance, create more accurate schedules, and reduce call times to the transit information center. The ORION program will expand the traveler information center operations with improved call handling, transit trip planning software, and an internet web site [Ref. 3].

- In Washington DC, the Washington Metropolitan Area Transit Authority (WMATA) is initiating a 'smart bus' program to expand the fleet management and transit information operations of its fixed-route bus system. The 'smart bus' plan is expected to include AVL, automated dispatching software, automated fare collection, traffic surveillance cameras, and traffic signal prioritization. The transit information component of the 'smart bus' program will include in-vehicle voice annunciators and an improved passenger information system. WMATA currently has over 300 buses equipped with GPS driven voice annunciators and is expected in include this feature on its planned future buys of new buses (over 400 additional new buses to be equipped) [Ref. 14].

- In Chicago, the CTA is deploying an in-vehicle passenger information and communication system for all trains on its subway system. Primary features of this system will include in-vehicle automated announcements and passenger communication system, which allows passengers to communicate with the train operator. This ATIS is expected to be operational on the CTA's Red and Purple lines in early 2000, and on the agency's three other lines during the third quarter of 2000 [Ref. 14].

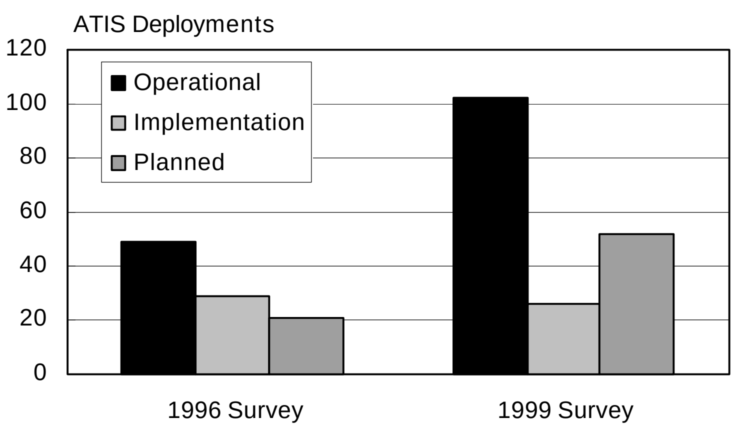
- In the San Francisco area, the Bay Area Rapid Transit (BART) expanded its existing station transit information to incorporate real-tine estimated time of arrival of each

[18] For this corridor operations, the Minneapolis MTC equipped 80 buses (of its 800 vehicle fleet) with a GPS based AVL system SmartTrack™ .

BART train on new station destination signs. The new electronic destination signs are found in all 39 BART stations. Updated information on train arrivals and destinations are provided at two-minute intervals. In order to comply with ADA requirements, BART is currently designing a digitized system of audio estimated time-of-arrival announcements for its passenger transit information system. The San Francisco Muni and BART systems have an ongoing program, called “Talking Signs,” to help visually-impaired transit patrons. The “Talking Signs” are fixed infrared transmitters which convey audio signals to either hand-held receivers or receivers at wayside stations . The “Talking Signs” are currently deployed at key BART and CalTrain stations and major bus route stations [Ref. 14].

7.1 Advanced Traveler Information System Deployments

Since 1995, there has been a significant increase in the number of deployments of advanced traveler information systems and in the number of transit systems implementing or planning the implementation of these systems. Figure 7-1 shows the growth in the number of advanced traveler information system deployments, based on the results of two recent surveys [Refs. 4, 5] conducted by the Volpe Center of the transit industry. As shown, the number of ATIS system deployments (currently operational, under implementation, and planned) has nearly doubled over the past five years, with the largest increases in the number of deployments that are currently operational (108% increase) and those that are being planned (147% increase).



ATIS Deployments

	1996 Survey	1999 Survey
Operational	49	102
Implementation	29	26
Planned	21	52
Total	99	180

Figure 7-1. Growth in ATIS Deployments

Figure 7-2 presents the distribution of the types of advanced traveler information systems, identified in the most recent Volpe survey, that are currently operational, under implementation or planned. Of the total number of ATIS deployments, 35% of the ATIS systems are directed to pre-trip planning applications. Approximately 19% of the deployments utilize (or plan to utilize) in-terminal system technologies, while in-vehicle and wayside system applications represent 13% and 8%, respectively, of the total deployments. A large percentage (nearly 25%) of the total deployments have not identified the type of ATIS technology planned for implementation.

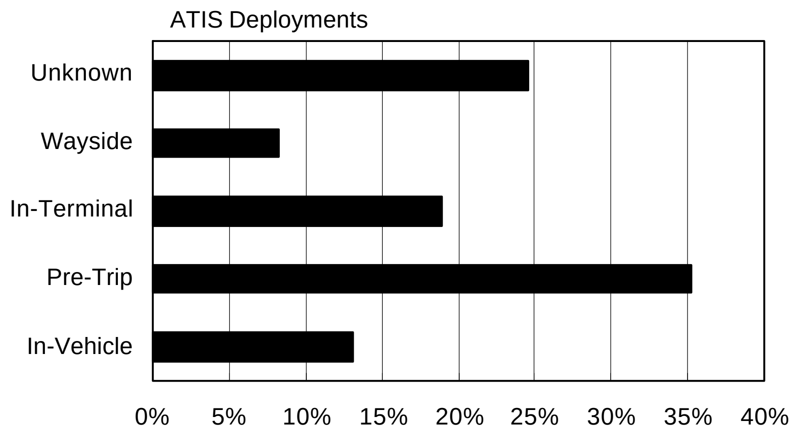
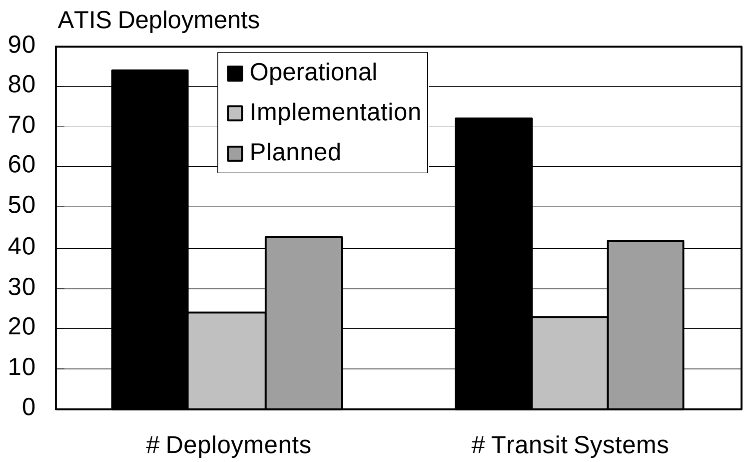


Figure 7-2. ATIS Technology Deployments

As a basis for estimating current and projected benefits of advanced traveler information systems, this analysis considered a total of 151 deployments of these systems that are currently operational, under implementation, or planned over the next five years. Figure 7-3 shows the stratification of the ATIS system deployments and the corresponding number of transit systems that have these systems operational, under implementation, and planned. Of the total 151 deployments considered over the 137 transit agencies, 56% are currently operational, 16% are under implementation, and the remaining 28% are planned for deployment.



ATIS Deployments

	Number of Deployments	Number of Transit Systems
Operational	84	72
Implementation	24	23
Planned	43	42
Total	151	137

Figure 7-3. ATIS Deployments Considered in the Analysis

A breakdown of these deployments by transit mode, along with the corresponding size of the transit vehicle fleet, is presented in Table 7-1.

Table 7-1. Advanced Traveler Information System Deployments Considered in the Analysis

	Operational		Under Implementation		Planned		Total	
Mode	Number of Deployments	Fleet Size	Number of Deployments	Fleet Size	Number of Deployments	Fleet Size	Number of Deployments	Fleet Size
FRB	62	16,479	21	7,663	41	6,477	124	30,619
DRT	2	84	1	243	0	0	3	327
CR	9	3,656	0	0	0	0	9	3,656
HR	4	735	1	342	2	1,271	7	2,348
LR	7	477	1	17	0	0	8	494
Total	84	21,431	24	8,265	43	7,748	151	37,444
FRB Fixed Route Bus, DRT = Demand Responsive Transit, CR = Commuter Rail, HR = High Speed Rail, LR = Light Rail								

A listing of the advanced traveler information system deployments (operational, under implementation, and planned) considered in this analysis is presented within Appendix B of this report.

7.2 Advanced Traveler Information System Benefits

The primary benefits most often cited by transit agencies with the deployment of advanced traveler information systems include:

- *Increased transit ridership and revenues*. Advanced traveler information systems have been found to be effective in promoting transit services to current and potential new transit patrons. The availability and ease of access to this information enhances the potential for keeping existing transit riders and attracting new users and transit revenues.
- *Improved transit service and visibility within the community*. The applications of advanced traveler information technologies are often used to demonstrate the full range of services and area coverage offered by public transportation in the community. This is especially true in larger metropolitan areas where extensive and more complex routes, fare structures, and multi-modal choices of transportation services often exist.
- *Increased customer convenience.* Applications of advanced traveler information systems provide a more convenient and potentially lower cost alternative for disseminating traveler information to transit riders, as compared to published transit schedules and telephone information systems. The application of these systems, especially in high density travel areas of cities (i.e., transportation centers, major city attractions, malls, etc.) has proved to be very effective and convenient to transit riders.
- *Enhanced compliance to Americans with Disabilities Act (ADA) requirements*. Advanced traveler information systems, including electronic displays, annunciators, and terminal/information kiosks, are effective technologies to enhance transit services to the hearing and visually-impaired patrons and to promote an agency's compliance with ADA requirements.

This analysis assumed that the primary benefits associated with the deployment of advanced information systems are accrued to transit agencies in the form of increased transit ridership and transit revenues from passenger fares. Projected advanced traveler information system deployment benefits (minimum, most likely, and maximum) were developed based on the following assumed variables (Table 7-2) and equation outlined below.

Table 7-2. APTS Advanced Traveler Information System Analysis Assumptions

Variable	For the period 1997-2000	Minimum Estimate	Most Likely Estimate	Maximum Estimate
% annual increase in: • transit ridership	1.0%	1.0%	2.0%	3.0%
• transit fares	n/a	1.0%	2.0%	3.0%
% increase in transit ridership from ATIS		1.0%	2.0%	3.0%

$[\text{Increased transit fare revenues}]_{Year}$ =

$[(\text{Projected annual passenger trips})_{Year}$ x (% increase transit ridership from ATIS) - $(\text{Projected annual passenger trips})_{Year}$] x [average fare per passenger $\text{trip}]_{Year}$

where:

$[\text{Projected annual passenger trips}]_{Year}$	Represents the transit agency's projected annual passenger trips in years 2000, 2003 and 2005, for ATIS deployments that are operational, under implementation and planned, respectively.
$[\text{average fare per passenger trip}]_{Year}$	Represents the transit agency's projected average fare per passenger trip in years 2000, 2003 and 2005, for ATIS deployments that are operational, under implementation, and planned, respectively.
[% increase in transit ridership from ATIS].	Represents the assumed increase in transit fare revenues resulting from the implementation and operation of ATIS deployments. The percentage savings is based on a probability distribution based on minimum, most likely and maximum values.
Year	Represents year 2000 for ATIS operational deployments, year 2003 for deployments under implementation, and year 2005 for planned ATIS system deployments.

This analysis projected that the total benefits, over the next ten years, for the advanced traveler information system deployments would range from $870.8 million (minimum estimate) to as high as $2.5 billion dollars (maximum estimate). The projected most likely estimate of the total advanced traveler information system benefits is nearly $1.7 billion dollars. These benefits are expressed in discounted, year 2000 present value dollars.

Figure 7-4 and Table 7-3 present the projected minimum, most likely and maximum benefits (in millions of discounted, year-2000 dollars) for ATIS deployments that are currently operational, under implementation and planned for deployment.

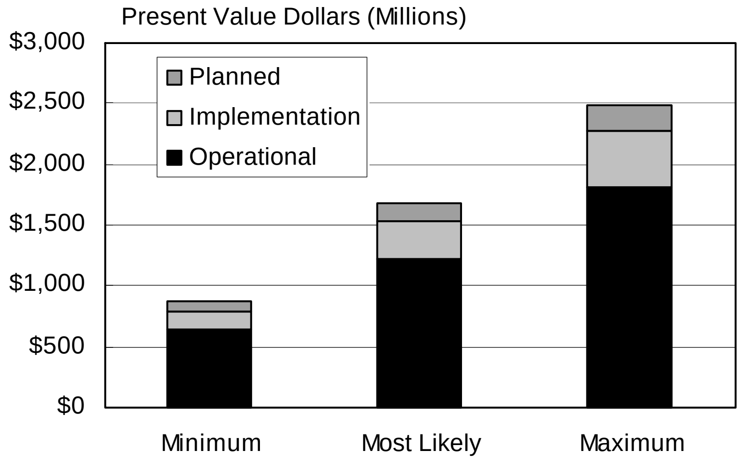


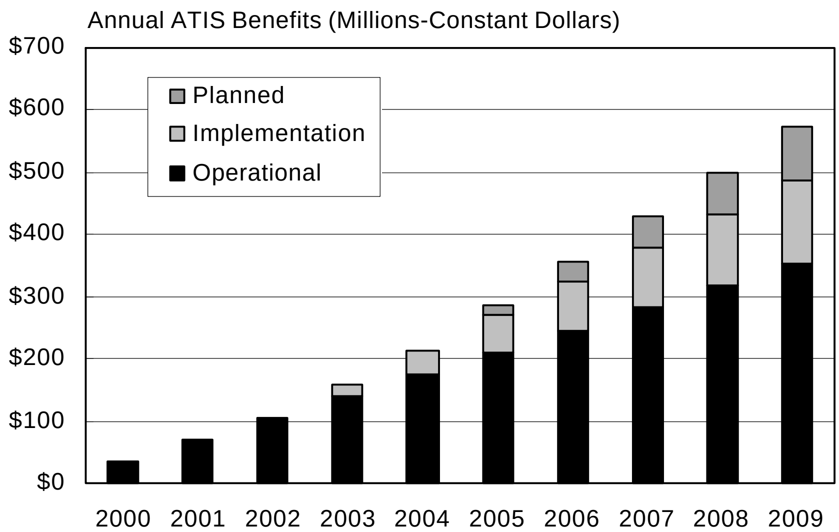
Figure 7-4. Advanced Traveler Information Benefits

Table 7-3. Advanced Traveler Information System Benefits
(in millions of discounted Y2000 dollars)

	# ATIS Deployments	ATIS Benefits Minimum Estimate	ATIS Benefits Most Likely Estimate	ATIS Benefits Maximum Estimate
Operational	84	$634.7	$1,223.0	$1,813.0
Implementation	24	$163.7	$317.7	$469.2
Planned	43	$72.5	$141.8	$210.0
Total	151	$870.8	$1,682.5	$2,492.2

Seventy-three percent of the total projected benefits for the APTS advanced traveler information systems are derived as a result of the currently operational deployments. Whereas, the ATIS system deployments that are currently under implementation and planned represent 19% and 8%, respectively, of the total benefits.

Figure 7-5 illustrates the distribution of the projected annual benefits, over the ten year analysis period, for the most likely ATIS benefits estimate. The annualized benefits reflected in this figure are expressed in millions of constant, year 2000 dollars.



Total Annual ATIS Benefits (Millions Constant Dollars)

Year	Benefits
2000	$35
2001	$70
2002	$106
2003	$160
2004	$215
2005	$286
2006	$358
2007	$429
2008	$501
2009	$572
Total	$2,732

Figure 7-5. Annual ATIS Benefits

A summary of the projected minimum, most likely and maximum advanced traveler information system benefits in constant and discounted, year 2000 dollars is presented in Table 7-4. This table also identifies the distribution of the ATIS benefits, by transit mode and by phase of deployment (operational, under implementation and planned). Over 74% of the total ATIS benefits are accrued by transit fixed-route bus deployments. Heavy rail, commuter rail and light rail transit deployments represent 12%, 9% and 5%, respectively, of the total ATIS benefits. Projected deployments for demand responsive transit systems represent less than 1% of the total ATIS benefits.

Table 7-4. Summary of Projected Advanced Traveler Information System Benefits

Minimum Estimate	Constant Year 2000 Dollars (Millions)				Discounted Present Value Dollars (Millions)			
	Operational	Implementation	Planned	Total	Operational	Implementation	Planned	Total
Fixed Route Bus	$696.7	$258.0	$103.9	$1,058.7	$440.1	$151.2	$58.0	$649.3
Demand Responsive	$0.1	$0.3	$0.0	$0.4	$0.1	$0.2	$0.0	$0.2
Commuter Rail	$121.2	$0.0	$0.0	$121.2	$76.6	$0.0	$0.0	$76.6
Heavy Rail	$118.6	$19.7	$25.9	$164.2	$74.9	$11.5	$14.5	$100.9
Light Rail	$68.2	$1.3	$0.0	$69.5	$43.1	$0.8	$0.0	$43.8
Total	$1,004.8	$279.3	$129.8	$1,413.9	$634.7	$163.7	$72.5	$870.8
Most Likely Estimate	Constant Year 2000 Dollars (Millions)				Discounted Present Value Dollars (Millions)			
	Operational	Implementation	Planned	Total	Operational	Implementation	Planned	Total
Fixed Route Bus	$1,342.6	$500.8	$203.4	$2,046.8	$848.0	$293.6	$113.6	$1,255.1
Demand Responsive	$0.2	$0.5	$0.0	$0.7	$0.1	$0.3	$0.0	$0.4
Commuter Rail	$233.5	$0.0	$0.0	$233.5	$147.5	$0.0	$0.0	$147.5
Heavy Rail	$228.5	$38.2	$50.7	$317.4	$144.3	$22.4	$28.3	$195.0
Light Rail	$131.4	$2.5	$0.0	$133.9	$83.0	$1.5	$0.0	$84.5
Total	$1,936.2	$542.1	$254.0	$2,732.3	$1,223.0	$317.7	$141.8	$1,682.5
Maximum Estimate	Constant Year 2000 Dollars (Millions)				Discounted Present Value Dollars (Millions)			
	Operational	Implementation	Planned	Total	Operational	Implementation	Planned	Total
Fixed Route Bus	$1,990.3	$739.6	$301.1	$3,031.0	$1,257.1	$433.5	$168.1	$1,858.7
Demand Responsive	$0.3	$0.8	$0.0	$1.0	$0.2	$0.4	$0.0	$0.6
Commuter Rail	$346.2	$0.0	$0.0	$346.2	$218.7	$0.0	$0.0	$218.7
Heavy Rail	$338.8	$56.4	$75.0	$470.2	$214.0	$33.1	$41.9	$288.9
Light Rail	$194.8	$3.7	$0.0	$198.5	$123.1	$2.2	$0.0	$125.2
Total	$2,870.5	$800.5	$376.0	$4,047.0	$1,813.0	$469.2	$210.0	$2,492.2

7.3 Advanced Traveler Information System Costs

The costs of transit advanced traveler information systems vary, depending on the transit mode and the features usually incorporated with each system application. In most cases, this study found that costs on current and planned ATIS deployments was very limited. Often cited costs were for limited applications or were cited as part of an overall demonstration project, which included the deployment of other APTS technologies (e.g., transit fleet management systems).

Table 7-5 presents a summary of representative costs from various transit advanced traveler information system deployments. Where information was available, the table identifies the extent of the transit deployment and the types of ATIS technologies deployed. The source of this information was the most recent Volpe survey [Ref. 5] on the application of ATIS technologies within the transit industry.

Table 7-5. Advanced Traveler Information System Costs

State	Transit System	Total Vehicle Fleet					Automated Transit	Deployment	System Cost	Notes
		MB	DRT	CR	HR	LR	Information			
AZ	Phoenix-Mesa SunRunner	23					T			Part of AVL project
CA	Contra Costa-Connection	116					P			Part of MTC's - Traninfo.
CA	LA-Access		243				P	8 locations.	$50.0 K	Approximate cost for start-up.
CA	LA-Commerce	10					U		$18.0 K	
CA	LA-LACMTA-Metro	2,413			30	69	I, T, P	All 44 rail stations	$6.3 M (enunciators)	$3.0 M for real-time information. Bus real time information in 2003.
CA	LA-Torrance	74					I			Part of Faretrans
CA	Oakland-AC Transit	694					I, T	Kiosks	$1.5 M	Demonstration project part of $14.5M AVL system.
CA	Riverside-RTA	107					I, T, W, P		$5.0 - 6.0 M	
CA	San Bernardino-OMNITRANS	137					P		$16,800/year for TRANSTAR DATABASE. $2,000/wk per station	
CA	San Diego-NCTD	154		21			U	100 kiosks. All AVL vehicles		Part of ITS Showcase
CA	San Joaquin-Smart	95					P		$600.0 K	Approximate cost
CA	SF-SamTrans	315					I	All fixed route service		Part of AVL $9.5M AVL system.
CA	Ventura Intercity Service	12					I, T, P		$23.0 K	
CO	Denver-RTD	849				17	T, W, P	16-owned by RTD; 66 others.	$4.5 M	
CT	New Britain Transit	11					U		$13.0 K	
CT	New Haven-CT Transit	111					T		$15,000 per Kiosk	
DE	Delaware-DTC	186					U	TBD		Part of $5.5 M Communications and AVL plan.
FL	West Palm-CoTran	154					U		$100.0 K	Approximate cost for CIS phone system.
GA	Atlanta-MARTA	783			238		T, W, P	100 FR; 238 HR; 81 Kiosks		
IA	Des Moines-Metro	93					P		$50.0K - $75.0K	Phone/computer
IL	Champaign-Urbana-MTD	94					U		$40.0 K	Interactive web site
IL	Peoria-GP Transit	48					P		$150.0 K	Phone
IL	Rock Island-Metro Link	66					T, W, P	2 locations	$4500 per location	
KY	Louisville-TARC	306					U		$132.0 K	Includes web site.
MA	Lawrence-MVRTA	45					I	33 buses	$10.0 K/bus	
MD	Baltimore-Maryland-MTA			134			T, P	16-19 stations		SMART Traveler
MI	Ann Arbor-AATA	69					I, T, P	All fixed route buses and one transit center		Part of $2 mil AVL system.
MI	Lansing-CATA	68					I	66 vehicles	$500.0 K	Part of AVL cost
MN	Rochester	26					P	8 kiosk locations	$102,000	
NJ	Port Authority-PATH				342		T	13 stations	$1.0 M	Approximate cost for hardware and software
NM	Albuquerque-Sun Tran	130					P			Included in $600K AVL costs.
NY	NY-MTA-Long Island Bus	318					T, P		$400.0 K	Approximate cost for CIS phone system.
NY	NY-MTA-Long Island RR			1,187			U		$100-$150K	Approximate cost
NY	NY-MTA-NYCTA	3,867					T, W, P	4 kiosks, 20 signs, 10 monitors	$1.7 M	
NY	NY-Rockland-Transport	51					P		$53.0 K	Web site
NY	NY-Westchester-Liberty	324					U		$1.0 M	
OH	Akron-Metro	138					I, T	75 vehicles		Part of AVL system.
PA	Altoona-AMTRAN	29					T			Part of $2.0 M planned AVL system
PA	Scranton-Colts	35					I	all vehicles		Part of AVL system.
RI	Providence-RIPTA	221					U		$100.0 K	web site
SC	Florence-PDRTA	6					U			Part of planned AVL project.
TN	Johnson City-JCT	10					T, W, P	7 kiosks	$200.0 K	Approximate cost ATIS; Kiosks, Internet access
TX	San Angelo-Antran	7					U		$52.0 K	
VA	Prince William-PRTC	75					I, T			Part of AVL system cost.
VA	Norfolk TRT	168					P		$400.0 K	Real time information from AVL system.
VA	VA-VRE			71			T, P		$1.0 M	Plans to tie to AVL for real-time information
WA	Vancouver-C-Tran	105					T	2 locations	$40.0 K	
WI	Milwaukee-Waukesha Metro	20					P		$50.0 K	Approximate cost
WI	Racine-Belle Urban System	42					P		$100.0 K	Approximate cost

Legend: I = In-vehicle; W = wayside; T = Terminal; P = Pre-trip planning; U = Other/Unknown
Source: APTS 1999 Deployment Survey Data; Volpe Center

Section 8
Transit Intelligent Vehicle Initiative

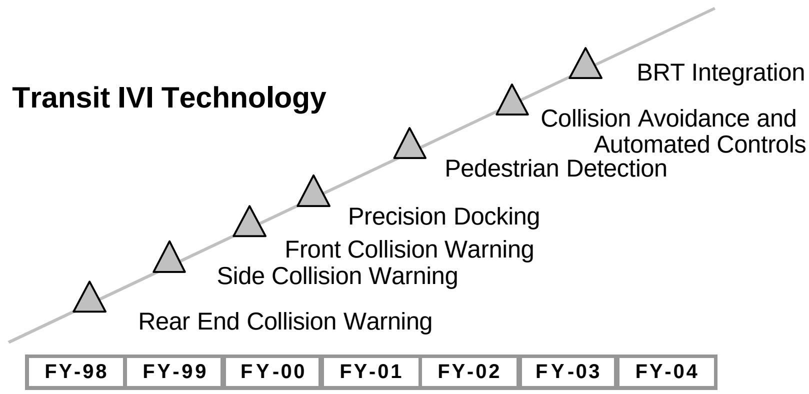
The Federal Transit Administration's Intelligent Vehicle Initiative (IVI) is an element of the U.S. Department of Transportation's Intelligent Vehicle Initiative Program, which is designed to improve the safety of transportation services through the application of advanced vehicle technologies. The IVI Program focuses on the development, evaluation, and deployment of vehicle collision warning and driver information and assistance systems to reduce motor vehicle crashes. By integrating driving assistance and vehicle collision warning systems, IVI systems will help transit vehicle operators process information, make decisions, and operate their vehicles more safely and effectively [Ref. 28].

8.1 Transit Intelligent Vehicle Initiative Program Activities

The FTA's Transit IVI program is a multi-year cooperative research program of the DOT and the transit industry to develop advanced intelligent vehicle systems, integrate them into vehicles and appropriate infrastructure, and evaluate their performance in real-world conditions. A Transit IVI needs assessment was conducted to synthesize existing information, and to identify and prioritize industry requirements and problems which may lend themselves to solutions involving IVI technologies. Through the needs assessment, critical Transit IVI applications were identified that would have the most significant impact in transit accident reduction and integration within transit vehicles and operations [Refs. 29, 30].

The Transit IVI program will conduct research, analyses, field tests and evaluations aimed at developing selected deployable transit vehicle IVI technologies and evaluating their performance within the next five years. Transit IVI technologies will initially be directed to bus and demand-responsive transit operations with potential future applications for rail and integrated inter-modal systems. Current areas of Transit IVI research, analysis and operational testing include: rear collision impact warning, frontal collision warning, side impact/lane change merge collision warning systems, road departure warning systems, pedestrian/passenger sensing systems, precision maneuvering and docking systems, and human factors associated with driver-vehicle interface systems. Evaluations of the Transit IVI technologies will be conducted on fixed-route bus systems and under the FTA's Bus Rapid Transit (BRT) Initiative. The BRT program focuses on the integration of advanced technology buses, APTS technologies, urban design enhancements, new service strategies, and traffic engineering enhancements to increase transit ridership and the quality of transit service. Some of the transit service innovations planned under BRT program include: deployments of traffic signal prioritization systems, exclusive right-of-ways, enhanced bus stations, vehicle location systems, pre-paid and electronic fare collection systems, advanced design buses that are highly accessible and maneuverable, transit-oriented land-use deployments, and advanced transit service operating strategies [Ref. 31].

Figure 8-1 illustrates a current timeline of major Transit IVI activities.



Source: FTA APTS Briefing to National Intelligent Vehicle Initiative Meeting, July 19-20, 2000

Figure 8-1. Timeline of Transit IVI Technologies

Primary activities currently underway in the development of Transit IVI technologies include:

- *Transit IVI Rear Impact Collision Warning System* - Working with the Ann Arbor Transportation Authority and their partners, Veridian ERIM International, and UCAL-PATH Berkeley, the FTA is sponsoring research of a Rear Impact Collision Warning System (RICWS) for transit buses. Research efforts under this project will focus on 1) an analysis of available crash data and the identification of critical crash scenarios; 2) the development of functional requirements of a RICWS; 3) the installation of a prototype system for field test evaluation; 4) the collection, analysis, and validation of baseline performance data; and, 5) the development of preliminary performance specifications for a RICWS [Ref. 32].

- *Transit IVI Side Collision Warning System* - In conjunction with Carnegie Mellon University, the Port Authority of Allegheny County (PAT), and the Pennsylvania DOT, the FTA is sponsoring a research program to investigate, develop, and test performance specifications for a transit bus side collision warning system (SCWS). Research activities will focus on: 1) analyzing available accident/incident data; 2) developing preliminary performance specifications; 3) investigating the current state of the art of side collision warning systems; 4) selecting a test system for evaluation; and, 5) validating performance specifications for a SCWS. Current plans call for the installation of side collision warning systems on a fleet of 100 PAT buses and the evaluation of the performance of SCWS in FY 2001. [Refs. 33, 34]

- *Transit IVI Frontal Collision Warning System* - Under a program involving San Mateo County Transit, UCAL-PATH Berkeley; Caltrans, the Gillig Corporation, and an advisory committee made up of nine mid-California transportation agencies, the FTA is sponsoring research in a transit bus frontal collision warning system (FCWS). The goal of this project is to develop the technical and requirement specifications for a forward-looking, transit vehicle mounted crash warning system, capable of operating in a low-speed urban and suburban driving environments. Current plans call for the development and installation of the system on two transit vehicles for field-test and system evaluation. The results of the field-test evaluations will be used to define the functional requirements and preliminary performance specifications for FCWS development. [Ref. 35]

- *Transit IVI Collision Avoidance Driver-Vehicle Interface* - This study, which was conducted under the Small Business Innovative Research (SBIR) Program, focused on the development of a preliminary driver-vehicle interface (DVI) for a transit bus longitudinal and lateral collision avoidance system. The study was conducted by Foster Miller, Inc. in collaboration with the Massachusetts Bay Transportation Authority (MBTA). The study focused on: 1) a characterization of a transit bus operational environment; 2) the identification of specific crash scenarios; 3) the development of an integrated model to identify crash intervention opportunities for transit bus collision avoidance system; 4) a review of previous collision avoidance systems research; and, 5) the development of DVI functional requirements for a transit bus collision avoidance system. [Ref. 35]

8.2 Transit Intelligent Vehicle Initiative Analysis Assumptions

Recent studies [Refs. 33, 36, 37] on Intelligent Vehicle Initiatives conducted for the ITS Joint Program Office, the National Highway Traffic Safety Administration (NHTSA), and the Federal Transit Administration have found that significant benefits can be achieved with the adoption of collision warning, collision avoidance and driver assistance technologies. Primary benefits most often cited are reductions in the incidence of accidents and the associated losses in passenger and pedestrian fatalities, injuries and property damage.

This analysis estimated the benefits of the Transit IVI program based on projected reductions of transit vehicle accidents and the resultant savings in the from of avoided losses in fatalities, injuries and property damage claims.

There are a number of data sources available that characterize the nature of highway and transit accidents. These include the FTA's National Transit Data Reporting System and Safety Management Information Statistics (SAMIS), and NHTSA's Fatal Accident Reporting System (FARS) and General Estimates System (GES). This analysis used the FTA's SAMIS data as the primary source of data on the incidence of transit accidents, transit-related fatalities, injuries and property damage losses. The SAMIS data are a compilation of transit accident, casualty and crime statistics, uniformly collected under the FTA's National Transit Database (NTD) Reporting System. Approximately 400 transit agencies throughout the country report transit accidents under the FTA-NTD system. The FTA SAMIS data are summarized by vehicle mode (motorbus, heavy rail, light rail, demand responsive transit) and, for motorbus operations, by class of transit agency.[19] A summary of the NTD-SAMIS motorbus accident data used in this analysis is presented in Appendix D of this report.

Presented in Table 8-1, are normalized rates (on a per passenger mile or per vehicle mile basis) of the incidence of <u>transit motorbus</u> accidents, collisions, fatalities, injuries, and property damage claims used in the analysis. These rates were determined by statistical averages over a nine-year SAMIS reporting period (1990-1998) for the various classes of transit agencies.

[19] The FTA's SAMIS data reports transit safety data, for motorbus operations, by classes of transit agencies representing the size of the transit agency. The classification used is: agencies having motorbus fleets greater than 500 vehicles, 100-500 vehicles, and less than 100 vehicles.

Table 8-1. SAMIS Incident/Accident Data (1990-1998)

SAMIS Accident/Incident Data		Urban areas with bus fleets		
Normalized data for the period 1990-1998		> 500 buses	100-500 buses	< 100 buses
# incidents	per million passenger miles	3.321	2.563	2.606
# fatalities	per million passenger miles	0.005	0.006	0.008
# injuries	per million passenger miles	2.740	2.007	2.185
# collisions **	per million vehicle miles	24.273	15.028	9.288
property damage (Ks $)	per million vehicle miles	21.303	17.005	14.534

** (excludes suicides)

Source: FTA's NTDB-Safety Management Information System

For each of the classes of transit agencies, the analysis projected the growth of transit motorbus ridership, transit motorbus service provided (vehicle-miles), and the size of motorbus fleet for the analysis period 2000-2009 using the most current 1998 National Transit Database data presented in Table 8-2. The projections were made using the minimum, most likely, and maximum rates for the expected growth in transit motorbus ridership, service supplied, and size of fleet as defined in Table 8-3. These values for the growth in transit motorbus ridership, service supplied and size of motorbus fleet were defined as analysis sensitivity variables (minimum, most likely, and maximum) using a triangular distribution for each of the variables as input to an @Risk simulation analysis process[20].

Table 8-2. 1998 National Transit Database Data (Motorbus Operations)

1998 NTD Motorbus Data	Urban Areas with Bus Fleets			Total MB
	> 500 Buses	100-500 Buses	< 100 Buses	Operations
# Passenger trips (millions)	2,954	1,334	465	4,754
# Passenger miles (millions)	9,510	6,417	1,947	17,874
# Passenger miles / passenger trip	3.2	4.8	4.2	3.8
# Vehicles (available for service)	30,397	20,516	9,916	60,830
# Vehicles (for maximum service)	22,704	15,324	7,407	45,435
# Vehicle miles (millions)	880	683	296	1,858
Average vehicle mileage/year	38,756	44,540	39,924	40,897
# New bus deliveries / year	3,022	2,040	986	6,047

Source: FTA's 1998 National Transit Database (Motorbus operations)

Table 8-3. Analysis Sensitivity Variables

	% annual increase 1998-2000	% Annual Increase 2000-2009		
		Minimum Estimate	Most Likely Estimate	Maximum Estimate
Transit ridership (passenger trips)	1.0%	1.0%	2.0%	3.0%
Transit service (vehicle miles)	2.0%	2.0%	3.0%	5.0%
% Annual growth in fleet	2.0%	2.0%	3.0%	4.0%

[20] The @Risk simulation process, used in the determination of minimum, most likely, and maximum projected benefits is defined in Appendix A of this report.

Figures 8-2 and 8-3 illustrate, respectively, the growth of the transit motorbus fleet over the 1992-1998 timeframe and the number of new bus deliveries for the period 1989-1998.

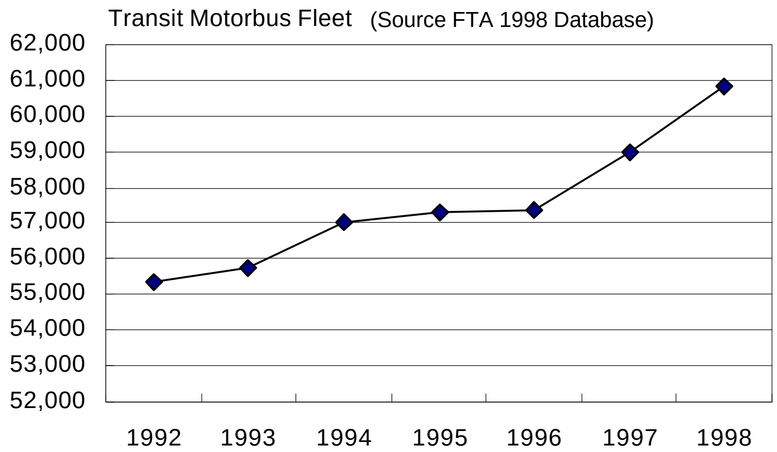


Figure 8-2. Growth of Transit Motorbus Fleet

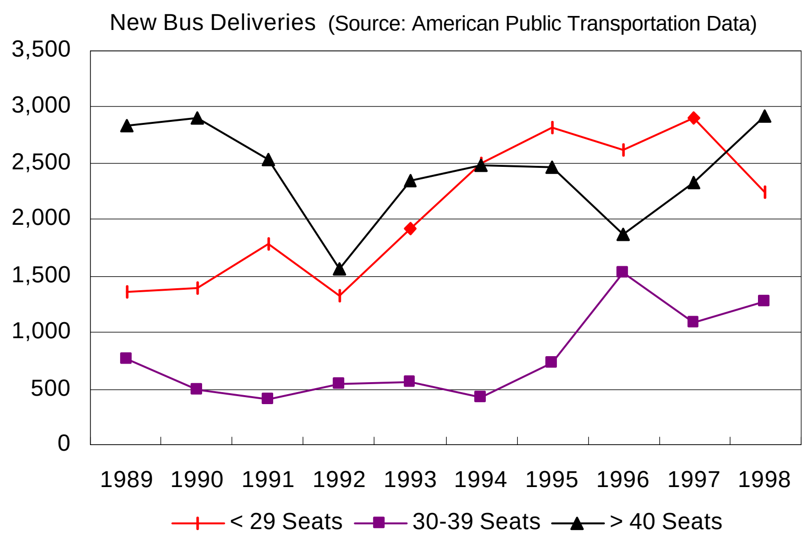


Figure 8-3. Transit New Bus Deliveries

This analysis assumed that Transit IVI collision warning technologies would be introduced within the transit motorbus fleet based on the following assumptions[21]:

- IVI technologies would be introduced into the motorbus market as original equipment on new bus deliveries (as opposed to retrofitting existing vehicle fleets). The likely introduction rate of IVI technologies on new bus deliveries would range from 2%-5% per year.
- IVI technologies would be introduced primarily on motorbus fleet operations in large urban transit systems and on routes that have high passenger volumes and high traffic density.

[21] These assumptions were based on discussions with the Transit IVI Program Office and Carnegie-Mellon University.

- The deployment of IVI technologies would be phased with the delivery of new buses starting with an initial introduction date of 2003 for the availability of such systems.

Consistent with these assumptions, Table 8-4 identifies the assumed values (minimum, most likely, maximum) of the percentage of new vehicle (motorbus) deliveries that would be equipped with IVI collision avoidance technologies. The expected percentages of new vehicle deliveries to be equipped with Transit IVI technologies were defined as analysis sensitivity variables (minimum, most likely, and maximum) using a triangular distribution for each of the variables as input to an @Risk simulation analysis process.

Table 8-4. Assumed Values for Deployment of IVI Technologies

% New bus deliveries with IVI technologies		Minimum Estimate	Most Likely Estimate	Maximum Estimate
Urban areas with fleets:	> 500 buses	3.0%	4.0%	5.0%
	100-500 buses	2.0%	3.0%	4.0%
	< 100 buses	1.0%	2.0%	3.0%
Initial year of IVI technology introduction		2003	2003	2003

This analysis examined past studies [Refs. 30, 36, 37], conducted for the FTA, NHTSA, and the ITS-JPO, which characterized the frequency and types of accidents (involving bus, motor coach and trucks) in order to identify those classes of accidents that may be addressed by IVI technologies. In the study conducted by the ITS-JPO [Ref. 37], crash data from NHTSA's Fatal Analysis Reporting System (FARS) and General Estimates System (GES) were analyzed to gain a better understanding of the nature and significance of the factors contributing to motor vehicle crashes. Using 1994 GES data for all vehicle types, the study found that three of the most frequent classes of crash types (rear-end, intersection, and road departure) accounted for nearly 75% of all crashes. The majority of these were rear-end crashes (26%) and intersection crashes (29%). Analysis of the GES data from 1994, showed that there were 1.66 million rear-end crashes, which accounted for 920,000 injuries and 1,160 fatalities. In this study, NHTSA estimated that 50% of these crashes could have been avoided by a collision avoidance system which could sense stopped or slower-moving vehicles in the forward lane.[22] Intersection crashes, which represented the largest percentage, accounted for 1.85 million crashes in 1994. As part of NHTSA funded Intersection Collision Avoidance System (ICAS) development project, Veridian Engineering conducted a detailed analysis of the intersection crash scenarios, the causal factors involved in these crashes, and the effectiveness of appropriate countermeasures and/or collision avoidance systems. The Veridian analysis found that an in-vehicle ICAS system was not capable of preventing crashes in all the intersection crash scenarios. The ICAS system was capable of addressing crashes in two of the larger crash scenarios, which (when combined) represent 54% of all types of intersections crashes. The study also found that the ICAS system was capable of addressing (to a lesser degree) intersection crashes that involve a violation of a traffic control system. These types of crashes represent nearly 44% of all intersection crashes.

In a more recent study [Ref. 30] conducted for the FTA's IVI Program, GES crash data for the years 1994 -1996 were analyzed to identify the types of accidents involving motor coaches[23]. The study found that the majority of all crashes (84%) fall within four categories: lane

[22] Referenced a Preliminary Assessment of Crash Avoidance Systems Benefits, NHTSA Benefits Working Group, October 1996.
[23] Under the GES system, the motor coach vehicle class includes not only urban transit buses but also inter-city motor buses.

change/merge (36%); rear-end collisions (21%); intersection collisions (18%); and parked vehicle (9%). Using this data, the study established five crash scenarios (backing up, lane change, rear-end, intersection and parked) and conducted a hazard risk assessment through an assignment of the potential risks and impacts, of each potential scenario. The study characterized the risk impact of each scenario, in terms of likelihood of occurrence and severity of impact, in order to identify the most promising applications for Transit IVI research opportunities. The study found that the highest risk crash scenarios for IVI research were intersection crashes in which the bus is struck by another vehicle and rear end crashes where the bus is struck by another vehicle. Crash scenarios identified as having a medium range of risk and severity impact were intersection crashes where the bus strikes another vehicle; rear end crashes in which the bus strikes another vehicle or object; and crashes that occur when the bus is backing up. The study concluded that further research, development, and evaluation of Transit IVI technologies to address these areas would provide additional information on the effectiveness of these technologies in the reduction of transit accidents, injuries and fatalities.

From the studies identified above, it is expected that Transit IVI equipped buses will be deployed in urban transit operations that generally experience a high number of accidents involving significant risk in terms of likelihood of occurrence and impact severity. Under a phased deployment of IVI equipped buses, starting in an initial deployment year 2003 and continuing through the year 2009, this analysis assumed that the likely effectiveness of IVI technologies in reducing the incidence of transit accidents, fatalities, injuries and property damage losses ranged from as low as 20% to as high as 40%, as presented in Table 8-5. These assumed values were defined as analysis sensitivity variables (minimum, most likely, and maximum) using a triangular distribution for each of the variables as input to an @Risk simulation analysis process.

Table 8-5. Assumed Effectiveness of Transit IVI Technologies

% Effectiveness of IVI technologies in reducing transit related:	Minimum Estimate	Most Likely Estimate	Maximum Estimate
Incidents	20%	30%	40%
Fatalities	20%	30%	40%
Injuries	20%	30%	40%
Vehicle collisions	20%	30%	40%
Property damage losses	20%	30%	40%

Through the analysis process, the number accidents, fatalities, injuries, and property damage losses avoided were determined as program benefits. The analysis quantified, in economic terms, the benefit of avoided fatalities and avoided injuries by using standardized values, established by the Office of Management and Budget (OMB) and the DOT Office of the Secretary (OST) on the value of passenger life and injury. The analysis assumed that 30% of all transit accident related injuries were serious injuries and the remaining 70% as minor injuries. Table 8-6 presents the OMB and DOT/OST standardized accident fatality/injury values used in the economic analyses.

Table 8-6. Standard Economic Values for Passenger Fatalities and Injuries

Value of passenger fatality and injury: (in thousands of dollars)	Willingness to pay	Emergency Medical Expenses	Legal / Court Costs	Total Cost
Fatality	$2,700.0	$0.0	$0.0	$2,700.0
Serious Injury	$482.0	$25.0	$11.0	$518.0
Minor Injury	$34.0	$2.0	$2.0	$38.0
Source: Standardized values established by OMB and DOT/OST				

8.3 Transit Intelligent Vehicle Initiative Program Benefits

The primary benefit to be derived, through the deployment of advanced Transit Intelligent Vehicle Initiative technologies, by transit agencies would be improved safety. This analysis estimated the benefits of the Transit IVI program based on projected reductions of transit vehicle accidents and the resultant savings in the from of avoided losses in transit accident fatalities, injuries and property damage claims.

This analysis projected that the total benefits, over the next ten years, for Transit IVI technology deployments would range from $498.0 million (minimum estimate) to as high as $1.2 billion (maximum). The projected most likely estimate is $819.6 million dollars. These benefits are expressed in discounted, year 2000 present value dollars. These estimated benefits are considered to be conservative since they were developed based on the assumption that Transit IVI technologies would be introduced into the transit bus market as a phased deployment on new bus deliveries, beginning in 2003. With the projected safety benefits of the Transit IVI program, many transit agencies may find it cost effective to retrofit portions of their existing fleets, that operate on high density, urban routes, with IVI collision warning systems. Under these conditions, the potential Transit IVI program benefits would be higher than the projected minimum, most likely, and maximum benefits, identified above.

Table 8-7 presents the projected minimum, most likely, and maximum benefits of the Transit IVI program in constant, year 2000 and discounted, present value dollars. The table also identifies, for each of the estimates, the value of the projected benefits, as derived in the form of avoided fatalities, injuries, and property damage losses. As shown, approximately 95% of the total Transit IVI program benefits are as a result of avoided injuries. Whereas, avoided accident fatalities and avoided property damage losses represent, respectively, 5% and less than 1% of the total program benefits.

Table 8-7. Transit IVI System Benefits

	Minimum Estimate	Most Likely Estimate	Maximum Estimate
Constant Year 2000 Dollars (Millions)			
Fatalities Avoided	$41.4	$70.6	$108.4
Serious Injuries Avoided	$687.7	$1,129.5	$1,686.2
Minor Injuries Avoided	$117.7	$193.3	$288.6
Property Damage Avoided	$3.6	$6.7	$10.7
Total	$850.4	$1,400.1	$2,094.1
Discounted Year 2000 Dollars (Millions)			
Fatalities Avoided	$24.3	$41.3	$63.5
Serious Injuries Avoided	$402.7	$661.2	$987.0
Minor Injuries Avoided	$68.9	$113.2	$168.9
Property Damage Avoided	$2.1	$3.9	$6.2
Total	$498.0	$819.6	$1,225.6

Figure 8-4 and Table 8-8 present the distribution of annual Transit IVI program benefits (for the most likely estimate) over the ten year analysis period (2000-2009). The benefits shown are in millions of discounted, present value dollars.

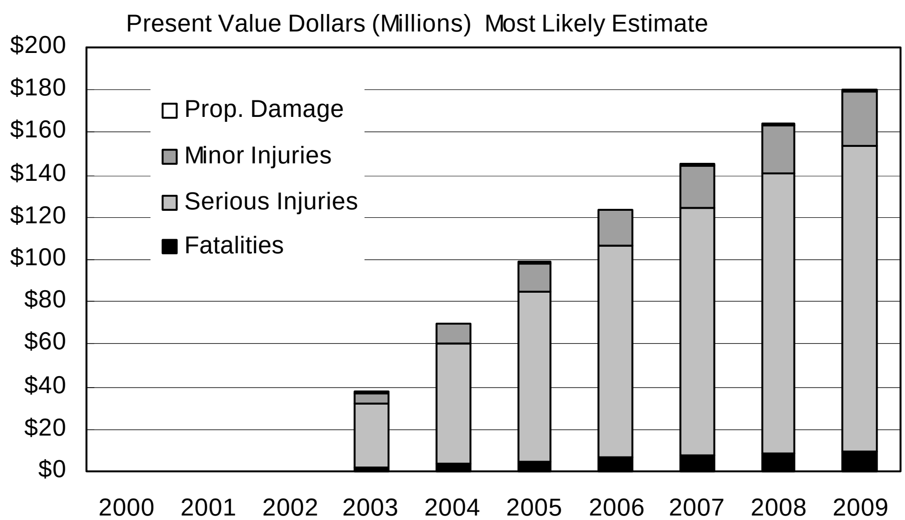
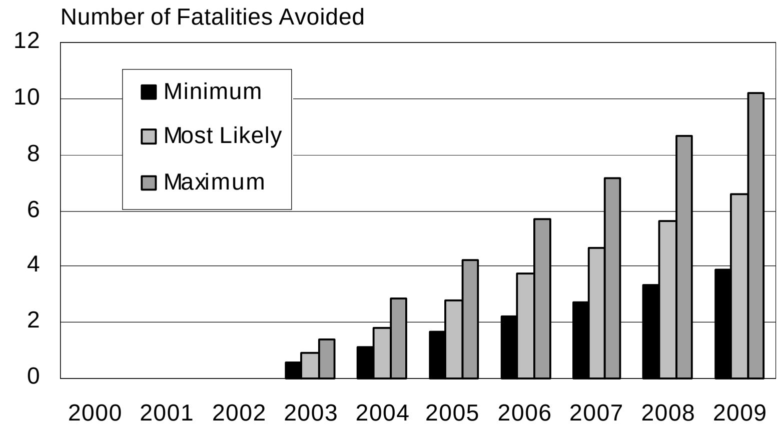


Figure 8-4. Transit IVI Program Benefits

The projected number of annual accident fatalities, injuries, and collisions avoided as a result of the introduction of Transit IVI technologies are presented, respectively, in Figures 8-5, 8-6, and 8-7. These figures show the projected number of fatalities, injuries, and collisions avoided for the minimum, most likely and maximum analysis cases considered. This analysis projected that the total number of transit accident fatalities that would be avoided, over the ten-year period, would range from 15 to 40 with a most likely estimate of 26 lives saved. The total number of transit accident injuries avoided, over the ten-year period, was projected to range from over 4,000 to nearly 11,000 persons injured. The projected most likely estimate of the number of avoided transit accident injuries was nearly 7,300. Avoided transit accident collisions, over the ten year period, ranged from an estimated 4,273 (minimum case) to as high as 10,880 (maximum case). The most likely estimate on the total number of accident collisions avoided through the introduction of Transit IVI technologies, for the period 2000-2009, was over 6,900.

Table 8-8. Time Distribution of Transit IVI Benefits (Most Likely Estimate)

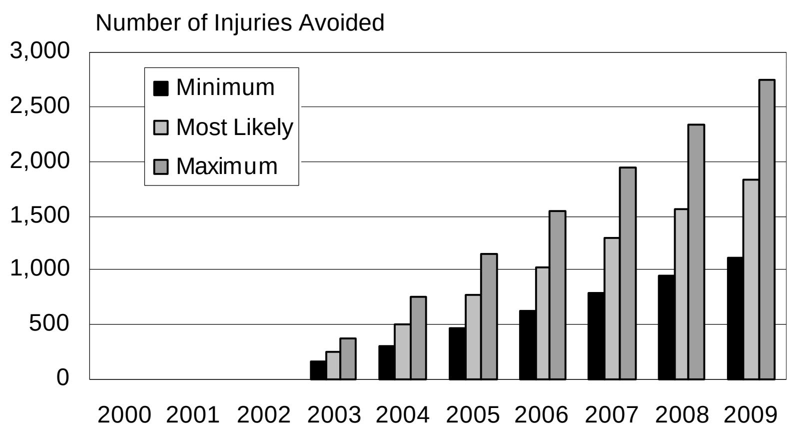
	Transit IVI Program Benefits (in Millions of Discounted, Present Value Dollars)				
Year	Avoided Fatalities	Avoided Serious Injuries	Avoided Minor Injuries	Avoided Property Damages	Total Benefits
2000	$0.0	$0.0	$0.0	$0.0	$0.0
2001	$0.0	$0.0	$0.0	$0.0	$0.0
2002	$0.0	$0.0	$0.0	$0.0	$0.0
2003	$1.9	$30.1	$5.2	$0.2	$37.3
2004	$3.5	$56.6	$9.7	$0.3	$70.1
2005	$5.0	$79.8	$13.7	$0.5	$98.8
2006	$6.2	$99.9	$17.1	$0.6	$123.8
2007	$7.3	$117.4	$20.1	$0.7	$145.5
2008	$8.3	$132.4	$22.7	$0.8	$164.1
2009	$9.1	$145.1	$24.8	$0.9	$179.9
Total	$41.3	$661.2	$113.2	$3.9	$819.6



Transit Accident Fatalities Avoided

Year	Minimum	Most Likely	Maximum
2000	0	0	0
2001	0	0	0
2002	0	0	0
2003	1	1	1
2004	1	2	3
2005	2	3	4
2006	2	4	6
2007	3	5	7
2008	3	6	9
2009	4	7	10
Total	15	26	40

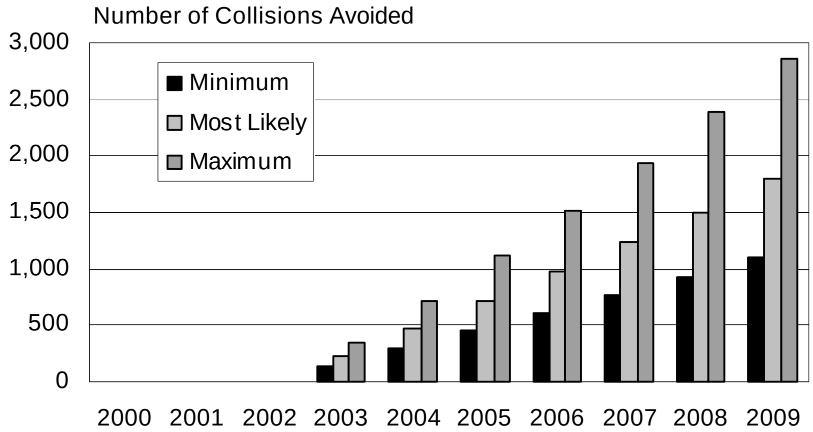
Figure 8-5. Transit Fatalities Avoided



Transit Accident Injuries Avoided

Year	Minimum	Most Likely	Maximum
2000	0	0	0
2001	0	0	0
2002	0	0	0
2003	155	254	378
2004	311	511	760
2005	470	770	1,147
2006	631	1,032	1,539
2007	792	1,298	1,937
2008	953	1,566	2,339
2009	1,113	1,837	2,751
Total	4,425	7,268	10,851

Figure 8-6. Transit Injuries Avoided



Transit Accident Collisions Avoided

Year	Minimum	Most Likely	Maximum
2000	0	0	0
2001	0	0	0
2002	0	0	0
2003	144	229	352
2004	293	467	721
2005	446	713	1,108
2006	603	969	1,515
2007	765	1,234	1,941
2008	928	1,508	2,388
2009	1,093	1,793	2,856
Total	4,273	6,913	10,881

Figure 8-7. Transit Collisions Avoided

Section 9

Summary of APTS Program Benefits

Table 9-1 presents a summary of the major program benefits that have been identified for the APTS system technologies.

Table 9-1. APTS Program Benefits

Fleet Management Systems	• Increased transit safety and security • Improved operating efficiency • Improved transit service and schedule adherence • Improved transit information
Operational Software and Computer Aided Dispatching Systems	• Increased efficiency in transit operations • Improved transit service and customer convenience • Increased compliance with transit Americans with Disabilities Act (ADA) requirements
Electronic Fare Payment Systems	• Improved security of transit revenues • Increased customer convenience • Expanded base for transit revenue • Reduced fare collection and processing costs • Expanded and more flexible fare structures
Advanced Traveler Information Systems	• Increased transit ridership and revenues • Improved transit service and visibility within the community • Increased customer convenience • Enhanced compliance with Americans with Disabilities Act
Transit Intelligent Vehicle Initiative	• Increased safety of transit passengers • Reduced costs of transit vehicle maintenance and repairs • Enhanced compliance with Americans with Disabilities Act

This analysis found that the projected benefits for all APTS technology deployments, that are currently operational, under implementation, or planned for deployment over the next ten years, would range from as low as $3.9 billion to as high as $9.6 billion, in discounted, present value dollars. The most likely estimate of the total APTS Program benefits (over the ten year period 2000-2009) is $6.7 billion, in discounted, present value dollars. Figure 9-1 presents the minimum, most likely and maximum estimates of total program benefits for each of the APTS technology areas.

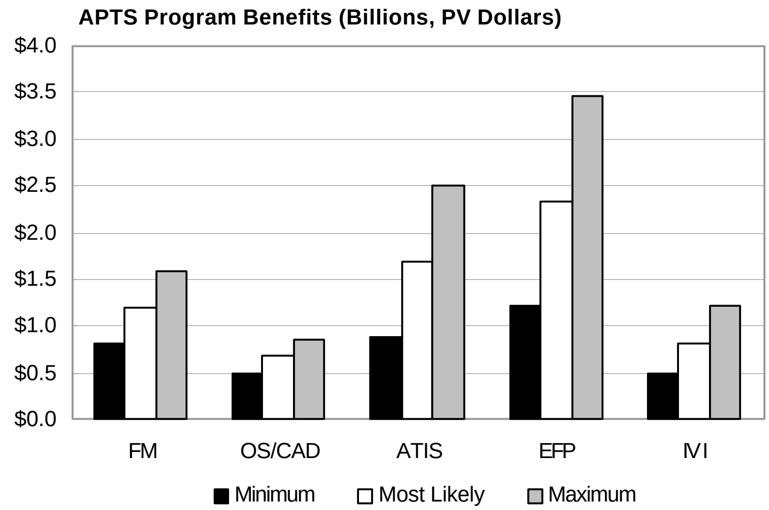


Figure 9-1. Total APTS Program Benefits

For the study's most likely estimate, the deployments of APTS electronic fare payment systems represent nearly 35% of the total projected benefits, while deployments of APTS advanced traveler information systems account for 25% of the total projected benefits. APTS fleet management systems and the planned deployment of APTS IVI technologies represent 18% and 12%, respectively, of the total projected APTS Program benefits. The deployment of APTS operational software and computer-aided transit dispatching systems represent the remaining 10% of the projected APTS Program benefits.

Table 9-2 presents a summary of the total projected minimum, most likely, and maximum program benefits of each APTS technology for the ten year period 2000-2009. These benefits are presented in both year 2000 constant dollars and discounted, present value dollars. The table also identifies, for each of the APTS technology areas, the distribution of total program benefits that are accrued from program deployments that are currently operational, under implementation or planned for implementation.

Table 9-2. Summary of APTS Program Benefits

Minimum Estimate	Constant Year 2000 Dollars (Millions)				Discounted Present Value Dollars (Millions)			
	Operational	Implementation	Planned	Total	Operational	Implementation	Planned	Total
Fleet Management Systems	$882.2	$262.5	$178.5	$1,323.3	$557.2	$153.9	$99.7	$810.8
AOS / CAD Systems	$570.8	$90.1	$159.2	$820.1	$360.5	$52.8	$88.9	$502.3
Automated Traveler Information	$1,004.8	$279.3	$129.8	$1,413.9	$634.7	$163.7	$72.5	$870.8
Electronic Fare Payment	$1,778.2	$6.8	$164.0	$1,948.9	$1,123.1	$4.0	$91.6	$1,218.7
Intelligent Vehicle Initiative			$850.4	$850.4			$498.0	$498.0
Total	$4,236.1	$638.7	$631.5	$6,356.7	$2,675.6	$374.3	$850.6	$3,900.5
Most Likely Estimate	Constant Year 2000 Dollars (Millions)				Discounted Present Value Dollars (Millions)			
	Operational	Implementation	Planned	Total	Operational	Implementation	Planned	Total
Fleet Management Systems	$1,300.7	$385.8	$263.0	$1,949.5	$821.5	$226.1	$146.9	$1,194.5
AOS / CAD Systems	$757.0	$122.7	$224.6	$1,104.3	$478.1	$71.9	$125.4	$675.5
Automated Traveler Information	$1,936.2	$542.1	$254.0	$2,732.3	$1,223.0	$317.7	$141.8	$1,682.5
Electronic Fare Payment	$3,404.4	$13.1	$319.1	$3,736.5	$2,150.3	$7.7	$178.2	$2,336.1
Intelligent Vehicle Initiative			$1,400.1	$1,400.1			$819.6	$819.6
Total	$7,398.3	$1,063.7	$2,460.8	$10,922.8	$4,672.9	$623.4	$1,411.9	$6,708.2
Maximum Estimate	Constant Year 2000 Dollars (Millions)				Discounted Present Value Dollars (Millions)			
	Operational	Implementation	Planned	Total	Operational	Implementation	Planned	Total
Fleet Management Systems	$1,724.9	$515.2	$359.1	$2,599.1	$1,089.5	$301.9	$200.5	$1,591.9
AOS / CAD Systems	$940.9	$158.3	$297.8	$1,397.0	$594.3	$92.8	$166.3	$853.3
Automated Traveler Information	$2,870.5	$800.5	$376.0	$4,047.0	$1,813.0	$469.2	$210.0	$2,492.2
Electronic Fare Payment	$5,037.8	$19.7	$486.0	$5,543.4	$3,182.0	$11.5	$271.4	$3,464.9
Intelligent Vehicle Initiative			$2,094.1	$2,094.1			$1,225.6	$1,225.6
Total	$10,574.0	$1,493.6	$3,613.0	$15,680.6	$6,678.8	$875.4	$2,073.7	$9,627.9

Appendix A
The @Risk Simulation Process

Risk analysis is a quantitative method, that uses probability distributions of input variables and simulations, to determine the range and probabilities of all possible outcomes of a decision situation.

This study utilized the @Risk™ simulation process, in conjunction with the Microsoft Excel spreadsheet tool, to develop estimates of the program benefits of the APTS system technology deployments. The @Risk™ tool uses probability distributions to describe uncertainties associated with key input variables. The probability distributions define the range of values (minimum to maximum) the input variables can assume and the likelihood of occurrence of each value within the range.

@Risk™ uses simulation, sometimes called Monte Carlo simulation, to perform the risk analysis. Simulation in this sense refers to a method whereby the distribution of possible outcomes is generated by letting the computer recalculate a spreadsheet model over a repeated number of iterations, each time using different randomly selected sets of values from the probability distributions of the defined input variables. In effect, the computer is trying a wide range of combinations of values for the input variables to simulate a large number of possible outcomes.

The @Risk™ simulation process uses two distinct operations:

- Selecting sets of values for the probability distribution functions that define the input variables of uncertainty.
- Recalculating the equations in the Excel worksheet to determine the output variables of interest.

The selection of values from the probability distributions is called sampling and each calculation of the worksheet variables is called an iteration. This analysis utilized the Latin Hypercube method of sampling to accurately recreate the probability distributions of the key model input variables. The key to the Latin Hypercube method of sampling is the stratification of the input probability distributions and the use of 'sampling without replacement'. The stratification divides the cumulative probability density curve into equal intervals on the cumulative probability curve (0 to 1). The number of stratifications of the cumulative distribution is equal to the number of iterations. A sample is then randomly selected from each interval of the input distribution, thus recreating the input probability distribution. This analysis utilized 1,000 iterations for each analysis simulation run.

The analysis utilized a triangular distribution to represent the probability distributions of the key input variables. The Triangular distribution function is defined by three values: a <u>minimum</u> value, a <u>most likely</u> value, and a <u>maximum</u> value. The direction of the "skew" of the triangular distribution is determined based on the size of the most likely value relative to the minimum and maximum values.

The Triangular probability density function f(x) is defined by the following:

$f(x) = 2(x-a) / (b-a)(c-a)$	if, $a <= x <= b$
$f(x) = 2(c-x) / (c-a)(c-b)$	if, $b < x <= c$

where a = minimum value, b = most likely value and c = maximum value.

While the Triangular cumulative probability distribution function F (x) is defined by the following:

$F(x) = 0$	if, $x < a$
$F(x) = (x-a)^2 / (b-a)(c-a)$	if, $a <= x <= b$
$F(x) = 1- [(c-x)^2 / (c-a)(c-b)]$	if, $b < x <= c$
$F(x) = 1$	if, $c < x$

where a = minimum value, b = most likely value and c = maximum value

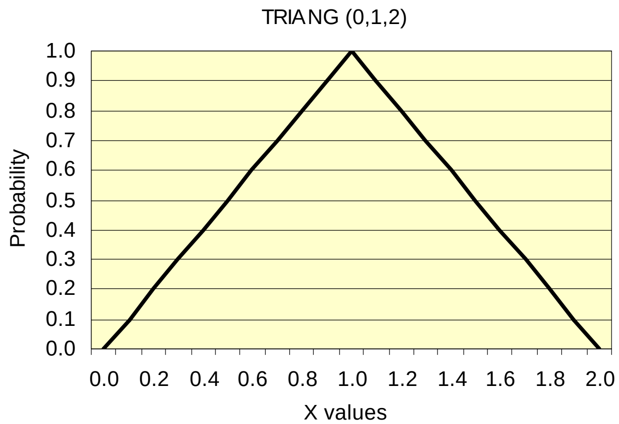
Presented below is an example of a triangular probability density and cumulative probability distribution function:

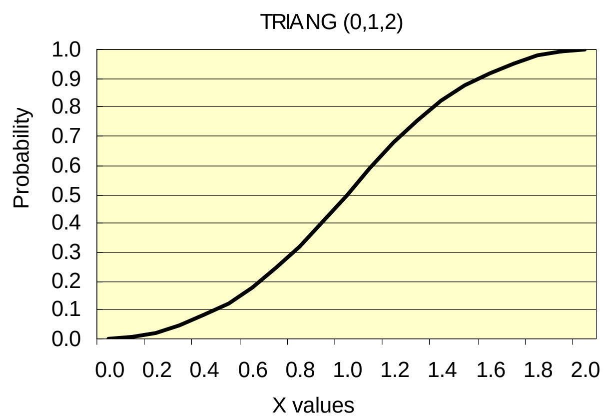
Triangular Distribution Function: TRIANG (a,b,c)

where: a = minimum value = 0

b = most likely value = 1

c = maximun value = 2





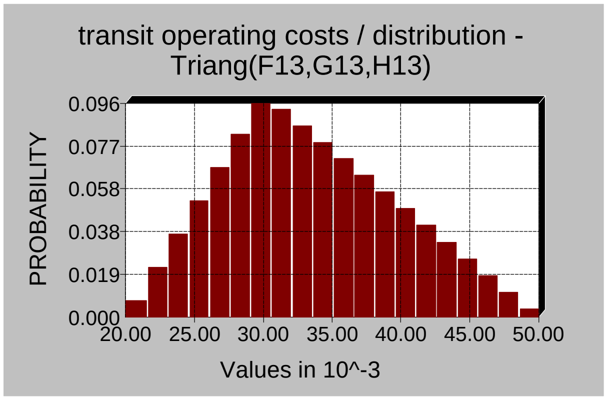
This analysis used the Triangular probability distribution function to represent the uncertainty of the following eight model input variables.

- % annual increase in transit operating costs
- % annual increase in transit ridership
- % annual increase in transit service supplied (VSM)
- % annual increase in transit fares
- % savings in non-revenue vehicle miles - Fleet Management

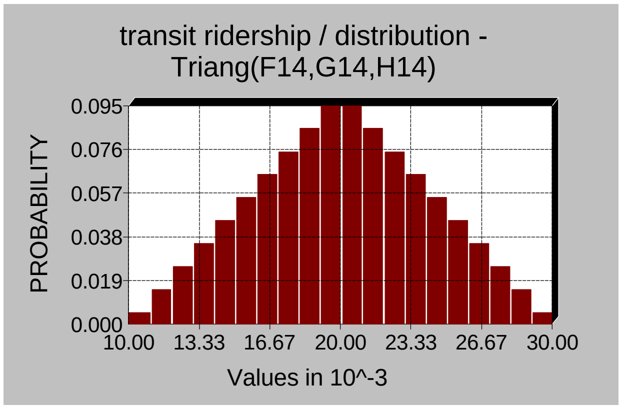
- % savings in non-revenue vehicle miles - OS/CAD
- % increase in transit ridership - ATIS
- % savings in transit revenues - EFP

Presented below are the minimum, most likely, and maximum values that were assumed for each variable. Also presented is a graphical representation of the Triangular probability distribution function of each variable.

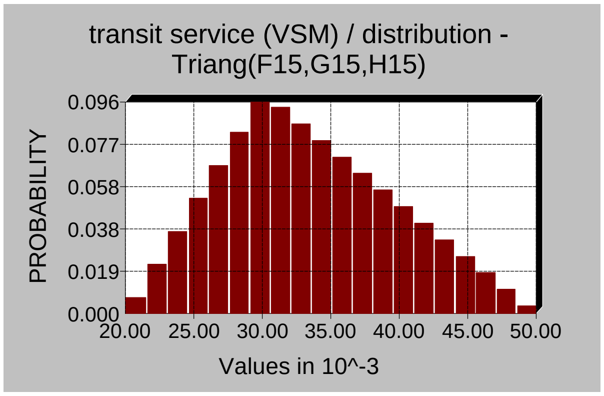
Input Variable % annual increase in transit operating costs @Risk Function: Triang (2,3,5)		
Minimum Value	Most Likely Value	Maximum Value
2%	3%	5%



Input Variable % annual increase in transit ridership @Risk Function: Triang (1,2,3)		
Minimum Value	Most Likely Value	Maximum Value
1%	2%	3%



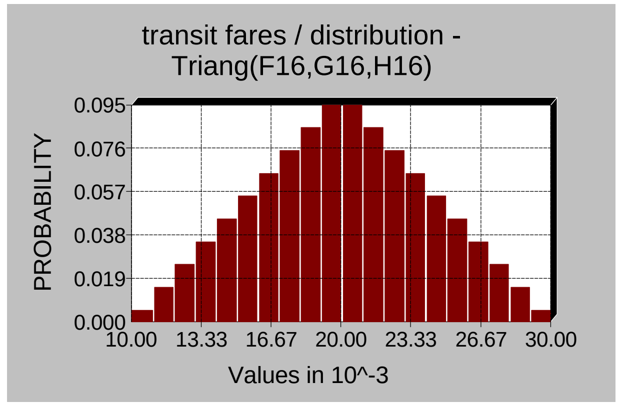
Input Variable % annual increase in transit service supplied (VSM) @Risk Function: Triang (2,3,5)		
Minimum Value	Most Likely Value	Maximum Value
2%	3%	5%



Input Variable
% annual increase in transit fares

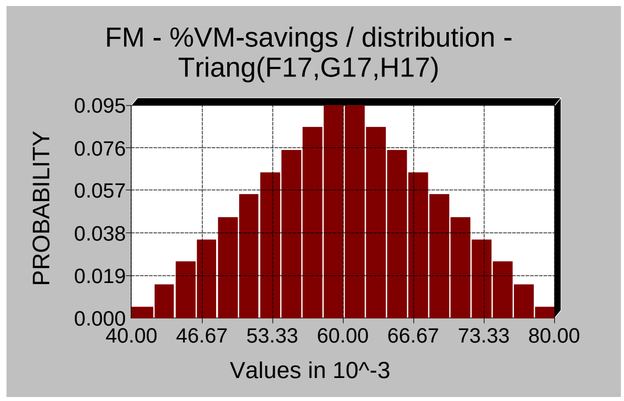
@Risk Function: Triang (1,2,3)

Minimum Value	Most Likely Value	Maximum Value
1%	2%	3%



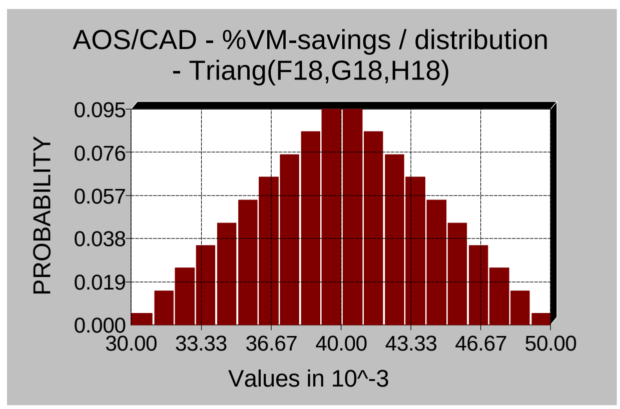
Input Variable
% savings in non-revenue vehicle miles - Fleet Management
@Risk Function: Triang (4,6,8)

Minimum Value	Most Likely Value	Maximum Value
4%	6%	8%

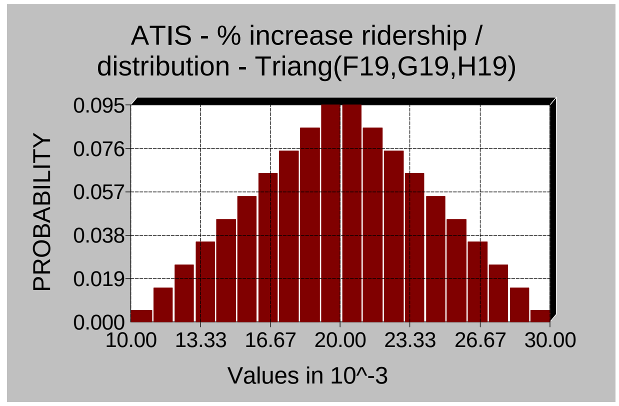


Input Variable
% savings in non-revenue vehicle miles -AOS / CAD
@Risk Function: Triang (3,4,5)

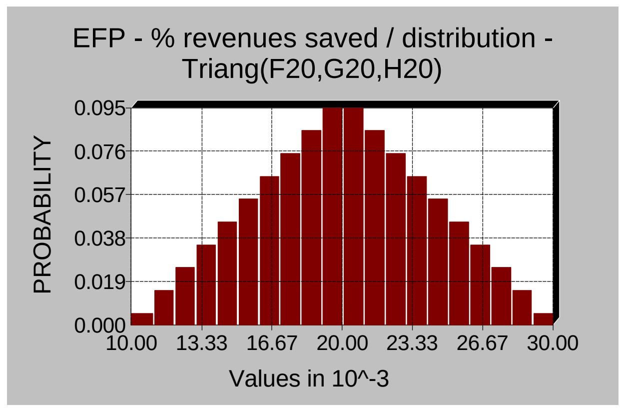
Minimum Value	Most Likely Value	Maximum Value
3%	4%	5%



Input Variable		
% increase in transit ridership - ATIS		
@Risk Function: Triang (1,2,3)		
Minimum Value	Most Likely Value	Maximum Value
1%	2%	3%



Input Variable		
% savings in transit revenues - EFP		
@Risk Function: Triang (1,2,3)		
Minimum Value	Most Likely Value	Maximum Value
1%	2%	3%



Appendix B
APTS System Deployments

List of tables within Appendix B.

Legend of notations used within the tables:

Tables B-1, B-2 and B-3

- SO - Signpost
- LC - LORAN-C
- DK - Deadreckoning
- OTR - Other
- GPS - Global Positioning System
- DGPS - Differential Global Positioning System
- U - Unknown
- [ ] - denotes a planned upgrade

Tables B-7, B-8 and B-9

- P - Pre-trip Planning
- I - In-vehicle
- T - Terminal
- W - Wayside
- U - Unknown
- [ ] - denotes a planned upgrade

Tables B-10, B-11 and B-12

- SC - Smart Card
- CC - Credit Card
- U - Unknown
- MS - Magnetic Stripe Card
- DC - Debit Card
- [ ] - denotes a planned upgrade

APTS System Deployments

Table B-1. Operational Fleet Management Systems

Index	State	Transit System	NTDB-ID	Number of Vehicles					Automated Vehicle Location	Vehicle Component Monitoring
				MB	DRT	CR	HR	LR		
1	AZ	Phoenix-RPTA	9136	53					GPS	
2	AZ	Tucson-Sun Tran	9033	203					GPS	
3	CA	Contra Costa-Connection	9078	116					GPS	
4	CA	Fresno-FAX	9027	92					GPS	✓
5	CA	LA-Access	9157		243				GPS, [U]	
6	CA	LA-Arcadia Transit	9044		18				GPS	
7	CA	LA-Gardena Bus Line	9042	45					GPS	✓
8	CA	LA-LACMTA-Metro	9154	2,413			30	69	SO, [DGPS]	[✓]
9	CA	LA-Santa Monica	9008	135					OTR	
10	CA	Modesto-MAX	9007	35					GPS	
11	CA	Riverside-RTA	9031	107					DK	
12	CA	Riverside Special Trans.	9086		19				GPS	
13	CA	San Francisco-Muni	9015	454				136	SO	
14	CA	San Joaquin-Smart	9012	95	36				DGPS	✓
15	CA	Santa Clara - Outreach	9160		155				DGPS	
16	CA	Santa Rosa-Sonoma County	9089	56					GPS	
17	CO	Denver-RTD	8006	849				17	DGPS	
18	FL	Ft. Lauderdale-TCRA	4077			34			GPS	
19	FL	Orlando-LYNX	4035	205					GPS	
20	FL	Tampa-Hartline	4041	189					SO	
21	GA	Atlanta-MARTA	4022	783			238		DGPS	✓
22	IA	Des Moines-Metro	7010	93	26				GPS	
23	IA	Five Seasons Trans	7008	40	33				GPS	✓
24	IL	Chicago-CTA/Cook Dupage	5134		160				OTR	
25	KY	Louisville-TARC	4018	306					SO	✓
26	MA	Hyannis - Cape Cod-CCRTA	1105	28	67				GPS	
27	MD	Baltimore-Maryland-MTA	3034			134			OTR	
28	MI	Ann Arbor-AATA	5040	69	47				SO	✓
29	MI	Detroit-SMART	5031	300	150				GPS	✓
30	MI	Lansing-CATA	5036	68					GPS	
31	MO	Kansas City-KCATA	7005	252					SO	
32	NC	Winston-Salem-WSTA	4012		20				U	
33	NJ	New Jersey Transit	2080	2,098		944			SO, GPS	
34	NM	Albuquerque-Sun Tran	6019		43				GPS	
35	NY	Albany-CDTA	2002	227					SO	✓
36	NY	NY-Westchester-Liberty	2079	324					SO, [GPS]	
37	NY	NYCDOT-Liberty	2117	86					SO	✓
38	OH	Akron-Metro	5010	138					GPS	
39	OH	Columbus-COTA	5016	303					SO	
40	OR	Portland-Tri-Met	0008	625	149				DGPS	
41	PA	Scranton-Colts	3025	35					GPS	✓
42	PR	San Juan-MBA	4086	250					SO, [GPS]	[✓]
43	PR	San Juan-PRHTA	4094	30					OTR	
44	TX	Dallas-DART	6056	543	96				GPS	
45	VA	Norfolk-TRT	3005	168					U	✓
46	VA	Prince William-PRTC	3070	75					GPS	
47	WA	Bremerton-Kitsap Transit	0020	119	47				GPS	
48	WA	Seattle-Metro	0001	1,114					SO	
49	WA	Spokane-STA	0002		87				GPS	
50	WI	Milwaukee-County	5008	535					DGPS	
51	WI	Sheboygan-ST	5088	29					LC	

‘Source: Advanced Public Transportation Systems Deployment in the United States’; The Volpe Center, U.S. DOT; January, 1999

APTS System Deployments

Table B-2. Fleet Management Systems Under Implementation

Index	State	Transit System	NTDB-ID	MB	DRT	CR	HR	LR	Automated Vehicle Location	Vehicle Component Monitoring
					Number of Vehicles					
1	AZ	Phoenix-Mesa SunRunner	9129	23					U	
2	CA	Ventura-Thousand Oaks	9165	4					GPS	
3	CT	New Haven-Gr. New Haven	1049		70				GPS	
4	FL	Broward County Mass Transit	4029	232					GPS	✓
5	IA	Sioux City-STC	7012	36	26				U	✓
6	IL	Chicago-RTA-CTA	5066	1,882					DK	✓
7	IN	Muncie-MITS	5054		11				U	
8	MD	Maryland-Ride-On	3051	267					DGPS	
9	MN	Minneapolis-St. Paul-MCTO	5027	894					GPS	
10	MN	St. Cloud-Metro Bus	5028	28	22				GPS	
11	NC	Asheville-City Coach	4005	16					SO	
12	NV	Las Vegas - ATC\VanCom	9152	236	127				DGPS	✓
13	NY	Buffalo-NFTA	2004	322					GPS	
14	NY	NY-MTA-Long Island Bus	2007	318	43				GPS	✓
15	NY	NY-MTA-NYCTA	2008	3,867					DGPS	✓
16	OH	Cincinnati-SORTA	5012	389	41				GPS	
17	OH	Cleveland-LAKETRAN	5117	30	64				GPS	
18	OH	Youngstown-WRTA	5024	43	6				GPS	
19	PA	Wilkes-Barre	3015	42					GPS	
20	TX	San Antonio-VIA	6011	498	423				DGPS	
21	VA	Roanoke-Valley Metro	3007	38					GPS	
22	VA	VA-VRE	3073			71			U	
23	WA	Richland-Ben Franklin	0018		62				GPS	

Source: Advanced Public Transportation Systems Deployment in the United States'; The Volpe Center, U.S. DOT; January, 1999

Table B-3. Planned Fleet Management System Deployments

Index	State	Transit System	NTDB-ID	MB	DRT	CR	HR	LR	Automated Vehicle Location	Vehicle Component Monitoring
					Number of Vehicles					
1	CA	Bakersfield-GET	9004	63	9				U	
2	CA	Fairfield	9092	26	5				GPS	✓
3	CA	Fresno-FAX	9027		21				GPS	
4	CA	LA-Norwalk	9022	22					GPS	
5	CA	LA-OCTA	9036	428	98				GPS	✓
6	CA	Lancaster-AV Transit	9121	31					GPS	✓
7	CA	Modesto-MAX	9007		11				GPS	
8	CA	Oakland-AC Transit	9014	694					GPS	✓
9	CA	Oakland-Wheel	9144	50	8				GPS	
10	CA	San Bernardino-OMNITRANS	9029	137	88				DGPS	✓
11	CA	San Diego- The Trolley	9054					85	GPS	
12	CA	Oceanside-NCTD	9030	154					GPS	
13	CA	San Diego Transit	9026	313					GPS	✓
14	CA	San Jose-SCCTD	9013	484				53	DGPS	
15	CA	SF-Golden Gate	9016	283					U	
16	CA	SF-SamTrans	9009	315	60				GPS	
17	CA	Tri Delta Transit	9162	26	18				GPS	
18	CO	Colorado Springs Transit	8005	51					DGPS	✓
19	CO	Fort Collins-Transfort	8011	23	32				U	
20	DE	Delaware-DTC	3075	186	109				GPS	✓

Source: Advanced Public Transportation Systems Deployment in the United States'; The Volpe Center, U.S. DOT; January, 1999

APTS System Deployments

Table B-3. Planned Fleet Management System Deployments (continued)

					Number of Vehicles					Vehicle Component
Index		Transit System	NTDB-ID		DRT	CR		LR	Location	
21	FL		4097		71					
22	FL		4030	47						
23	IA		7009	19						
24	IA		7011	18					GPS	
25		Iowa City-CAMBUS	7019		4				GPS	
26	IA		7013		25					
27	IL		5060	94					GPS	✓
	IL	Chicago-RTA-Pace		762					GPS	
29	IL		5057	66					GPS	✓
	IN	Bloomington-BPT		22					GPS	
31	IN		5104			56				
32	KS		7015	51					GPS	
33		Alexandria-ATRANS	6025						U	
34		Providence-GATRA	1064		47				DGPS	
	MI	Battle Creek-BCT		20	8					
36	NC		4093	25					GPS	✓
	NC	Raleigh-CAT			11				U	
	NC	Winston-Salem-WSTA		58					U	
	NE	Omaha-TA		139	24					✓
40		Portsmouth-COAST	1086		1				GPS	
	NM	Santa Fe Trails		30					U	
	NV	Reno-Citifare		63	47					
43	NY		2072	164					U	
44		NY-Rockland-Ride Sharing	2086						U	
45		NY-Rockland-Transport	2084						U	
46		Cleveland-RTA	5015		136		59		DGPS	✓
	OH	Dayton-RTA		222					U	
	OK	Tulsa-MTA		73	198					
49	OR		0007	97						
50	PA		3023	14					GPS	
51		Philadelphia-SEPTA	3019		495			147		✓
52		Providence-RIPTA	1001						GPS	
53		Florence-PDRTA	4056		142				GPS	
	SC	Sumter-Santee Wateree		25	49					
55	TN		4054		7					
56	TN		4004	140						
57	TX		6051	67						
58	TX		6006	165					U	✓
	TX	Houston-Metro		1,202	1,986					
60	WA		0001		535					
61	WI		5003	44						

Source: Advanced Public Transportation Systems Deployment in the United States'; January, 1999

APTS System Deployments

Table B-4. Operational OS/CAD System Deployments

				Number of Vehicles						Computer
Index	State	Transit System	NTDB-ID	MB	DRT	CR	HR	LR	Operational Software	Aided Dispatching
1	AK	Municipality of Anchorage	0012		31					✓
2	AL	Gadsden-Dial-A-Ride	4049		11					✓
3	AL	Montgomery-MAT	4044		8					✓
4	AZ	Peoria Transit	9140		11					✓
5	AZ	Phoenix-Glendale	9034		15					✓
6	AZ	Phoenix-RPTA	9136	53					✓	
7	CA	Bakersfield-GET	9004		9					✓
8	CA	City of Los Angeles	9147		116					✓
9	CA	Contra Costa-Connection	9078		40					✓
10	CA	Contra Costa-WESTCAT	9159		11					✓
11	CA	Fresno-FAX	9027		21					✓
12	CA	LA-Access	9157		243					✓
13	CA	LA-Arcadia Transit	9044		18					✓
14	CA	LA-LACMTA-Metro	9154				30		✓	
15	CA	Lancaster-AV Transit	9121		14					✓
16	CA	Merced County Transit	9173		20					✓
17	CA	Modesto-MAX	9007	35	11				✓	✓
18	CA	Oakland-Wheel	9144		8					✓
19	CA	Riverside Special Trans.	9086		19					✓
20	CA	Riverside-RTA	9031		36					✓
21	CA	San Bernardino-OMNITRANS	9029	137	88				✓	✓
22	CA	San Diego-NCTD	9030	154					✓	
23	CA	San Francisco-BART	9003				668		✓	
24	CA	San Joaquin-Smart	9012	95	36				✓	✓
25	CA	Santa Clara - Outreach	9160		155					✓
26	CA	SF-CalTrain	9134			93			✓	
27	CA	SF-SamTrans	9009	315					✓	
28	CA	Tri Delta Transit	9162		18					✓
29	CO	Denver-RTD	8006	849	540				✓	✓
30	CT	Danbury-HART	1051		27					✓
31	CT	Greater Bridgeport TD	1050		23					✓
32	CT	Hartford-Metro	1017		136					✓
33	CT	New Haven-Gr. New Haven	1049		70					✓
34	CT	Norwalk-Wheels	1057		33					✓
35	CT	Waterbury-GWTD	1104		13					✓
36	FL	Jacksonville-JTA	4040	188					✓	
37	FL	Oskaloosa County	4084		49					✓
38	FL	Tampa-Hartline	4041	189					✓	
39	FL	Vero Beach-Indian River	4104		136					✓
40	HI	Honolulu-DTS	9002		114					✓
41	IA	Des Moines-Metro	7010	93					✓	
42	IA	Five Seasons Trans	7008	40	33				✓	✓
43	IA	Waterloo-MET	7013		25					✓
44	IL	Champaign-Urbana-MTD	5060	94					✓	
45	IL	Chicago-RTA-Metra	5118			1,114			✓	
46	IL	Chicago-RTA-Pace	5113		372					✓
47	IL	Peoria-GP Transit	5056		10					✓
48	IL	Rockford-RMTD	5058		18					✓
49	IN	Lafayette-GLPTC	5051		8					✓
50	IN	Muncie-MITS	5054		11					✓
51	IN	South Bend-Transpo	5052		7					✓
52	LA	Alexandria-ATRANS	6025		3					✓
53	MA	Boston-MBTA	1003		37	346	408	173	✓	✓
54	MA	Fitchburg-MART	1061		99					✓
55	MA	Hyannis-Cape Cod-CCRTA	1105	28	67				✓	✓
56	MA	Lowell-LRTA	1005		21					✓
57	MA	Providence-GATRA	1064		47					✓
58	MA	Springfield-PVTA	1008	41					✓	

APTS System Deployments

					Number of Vehicles					Computer Aided
Index		Transit System	NTDB-ID		DRT	CR		LR	Software	
59	ME	Portland-RTP	1069		23					✓
60	MI	Ann Arbor-AATA	5040	69	47				✓	✓
61	MI	Bay City-Metro Transit	5029		23					✓
62	MI	Detroit-SMART	5031	300	150				✓	✓
63	MI	Jackson-JTA	5034		36					✓
64	MN	Minneapolis-St. Paul-MCTO	5027	894					✓	
65	MN	Moorhead-Transit	5026		2					✓
66	MN	Rochester	5092		5					✓
67	MO	Springfield-CU	7003		5					✓
68	MO	St. Louis-Bi-State	7006		63					✓
69	MO	St. Louis-MCT	5146		42					✓
70	NC	Charlotte-CTS	4008		48					✓
71	NC	High Point-Hitran	4011		3					✓
72	ND	Grand Forks-City Bus	8008		11					✓
73	NE	Omaha-TA	7002	139					✓	
74	NH	Nashua-City Bus	1087		10					✓
75	NJ	New Jersey Transit	2080	2,098					✓	
76	NM	Albuquerque-Sun Tran	6019		43					✓
77	NM	Santa Fe Trails	6077		29					✓
78	NY	Albany-CDTA	2002	227	28				✓	✓
79	NY	Broome County	2003		23					✓
80	NY	NY-MTA-Long Island RR	2100			1,187			✓	
81	NY	NY-MTA-Metro North RR	2078			880			✓	
82	NY	NY-MTA-NYCTA	2008		103					✓
83	NY	NY-Rockland-Ride Sharing	2086		15					✓
84	NY	Poughkeepsie-LOOP	2010		22					✓
85	NY	Rochester-RTS	2113		25					✓
86	OH	Cleveland-LAKETRAN	5117		64					✓
87	OH	Cleveland-RTA	5015	715	136				✓	✓
88	OH	Dayton-RTA	5017	222	50				✓	✓
89	OH	Middletown-MTS	5019		1					✓
90	OH	Youngstown-WRTA	5024	43	6				✓	✓
91	OK	Oklahoma City-COTPA	6017		65					✓
92	OK	Tulsa-MTA	6018		198					✓
93	PA	Altoona-AMTRAN	3011	29					✓	
94	PA	Philadelphia-PATCO	2075				121			✓
95	PR	San Juan-MBA	4086	250	27				✓	✓
96	RI	Providence-RIPTA	1001		30					✓
97	SC	Charleston-DASH	4110		11					✓
98	SC	Spartanburg-County	4088		35					✓
99	TN	Memphis-MATA	4003	194	34			10	✓	✓
100	TX	Amarillo-ACT	6001		4					✓
101	TX	Dallas-DART	6056	543					✓	
102	VA	Prince William-PRTC	3070	75					✓	
103	WA	Bellingham-WTA	0021		61					✓
104	WA	Olympia-IT	0019		27					✓
105	WA	Spokane-STA	0002		87					✓
106	WA	Tacoma-Pierce Transit	0003		135					✓
107	WI	Milwaukee-County	5008	535					✓	
108	WV	Charleston-KRT	3001		11					✓

Source: Advanced Public Transportation Systems Deployment in the United States'; The Volpe Center, U.S. DOT; January, 1999

APTS System Deployments

				Number of Vehicles						Computer Aided
Index		Transit System	NTDB-ID		DRT	CR		LR	Software	
1	AZ	Tucson-Sun Tran	9033	203					✓	
2	CA	LA-Long Beach Transit	9023	199					✓	
3	CA	San Jose-SCCTD	9013	484				53	✓	
4	CT	New Haven-CT Transit	1055	111					✓	
5	DE	Delaware-DTC	3075	186	109				✓	✓
6	FL	Broward County Transit	4029	232					✓	
7	IA	Sioux City-STC	7012	36	26				✓	✓
8	IL	Chicago-RTA-CTA	5066	1,882					✓	
9	KS	Johnson County Transit	7035		40					✓
10	MD	Maryland-Ride-On	3051	267					✓	
11	MN	St. Cloud-Metro Bus	5028	28	22				✓	✓
12	NH	Portsmouth-COAST	1086		1					✓
13	NJ	New Jersey Transit	2080		161					✓
14	NY	Buffalo-NFTA	2004	322				27	✓	
15	OH	Cincinnati-SORTA	5012	389	41				✓	✓
16	PA	Pittsburgh-PAT	3022	911				59	✓	
17	SD	Sioux Falls-The Bus	8002		58					✓
18	TN	Knoxville-K-Trans	4002		12					✓

Source: Advanced Public Transportation Systems Deployment in the United States'; The Volpe Center, U.S. DOT; January, 1999

APTS System Deployments

Table B-6. Planned OS/CAD System Deployments

Index	State		NTDB-ID	MB	Number of Vehicles	CR	HR		Operational Software	Dispatching
1	CA	Fairfield	9092	26	5				✓	✓
2	CA	LA-LACMTA-Metro	9154					69	✓	
3	CA	LA-Norwalk	9022	22	4				✓	✓
4	CA	Oakland-AC Transit	9014	694					✓	
5	CA	Oakland-Wheel	9144	50					✓	
6	CA	Tri Delta Transit	9162	26					✓	
7	CO	Fort Collins-Transfort	8011	23	32				✓	✓
8	CO	Greeley-The Bus	8010		5					✓
9	CT	New Haven-Milford	1107		11					✓
10	FL	Bradenton-MCT	4026	16	18				✓	✓
11	FL	Clearwater-Pasco Shuttle	4074	8	83				✓	✓
12	FL	Daytona Beach-VOTRAN	4032		104					✓
13	FL	Ft. Lauderdale-TCRA	4077			34			✓	
14	FL	Gainesville-RTS	4030	47					✓	
15	FL	Panama City-Bay Council	4085		42					✓
16	FL	Sarasota-SCTA	4046	37					✓	
17	GA	Augusta-APT	4023	30					✓	
18	IA	Dubuque, IA-KeyLine	7011	18	6				✓	✓
19	IA	Iowa City-CAMBUS	7019		4					✓
20	IL	Chicago-RTA-Pace	5113	762					✓	
21	IL	Rock Island-Metro Link	5057	66	6				✓	✓
22	IN	Evansville-METS	5043		14					✓
23	IN	Fort Wayne-PTC	5044		10					✓
24	MA	Springfield-PVTA	1008		89					✓
25	MD	Baltimore-Harford	3074	14	13				✓	✓
26	MI	Battle Creek-BCT	5030		8					✓
27	MI	Detroit-D-DOT	5119	601					✓	
28	MN	Duluth-DTA	5025	82	8				✓	✓
29	MO	Kansas City-KCATA	7005	252					✓	
30	MO	St. Joseph Express	7032	9	12				✓	✓
31	NC	Charlotte-CTS	4008	170					✓	
32	NC	Greensboro-GTA	4093		19					✓
33	NC	Winston-Salem-WSTA	4012		20					✓
34	NH	Portsmouth-COAST	1086	13					✓	
35	NV	Las Vegas - ATC\VanCom	9152	236	127				✓	✓
36	NY	Ithaca-TOMTRAN	2145	41	16				✓	✓
37	NY	NY-Hauppage-Suffolk Trans	2072	164	26				✓	✓
38	NY	NY-MTA-Long Island Bus	2007	318					✓	
39	NY	NY-MTA-NYCTA	2008	3,867			5,790		✓	
40	NY	NY-MTA-Staten Island	2099				64		✓	
41	NY	Syracuse-RTA-Centro	2018	174	17				✓	✓
42	OR	Eugene-LTD	0007	97					✓	
43	OR	Salem-Cherriots	0025	50					✓	
44	PA	Beaver County-BCTA	3023	14	25				✓	✓
45	PA	Philadelphia-SEPTA	3019	1,299					✓	
46	SC	Florence-PDRTA	4056		142					✓
47	SC	Sumter-Santee Wateree	4100	25	49				✓	✓
48	TN	Johnson City-JCT	4054	10					✓	
49	TX	Dallas-Mesquite	6070		13					✓
50	TX	Lubbock-Citibus	6010		13					✓
51	WA	Vancouver-C-Tran	0024	105					✓	
52	WI	Madison-MMT	5005	188	92				✓	✓
53	WI	Milwaukee-Paratransit	5112		502					✓
54	WI	Milwaukee-Waukesha Metro	5096		3					✓

Source: Advanced Public Transportation Systems Deployment in the United States'; The Volpe Center, U.S. DOT; January, 1999

APTS System Deployments

Table B-7. Operational Traveler Information Systems

Index	State	Transit System	NTDB-ID	Number of Vehicles					Traveler	Multi-modal Traveler
				MB	DRT	CR	HR	LR	Information	Information
1	AK	Municipality of Anchorage	0012	52					P	
2	CA	Contra Costa-Connection	9078	116					P	✓
3	CA	Davis-UNITRANS	9142	40					U	
4	CA	Fresno-FAX	9027	92					U	
5	CA	LA-LACMTA-Metro	9154	2,413			30	69	I, T, P	[✓]
6	CA	LA-SCRRA	9151			139			P	
7	CA	LA-Torrance	9010	74					I	
8	CA	Modesto-MAX	9007	35					P	
9	CA	San Bernardino-OMNITRANS	9029	137					P	✓
10	CA	San Diego- The Trolley	9054					85	P	✓
11	CA	San Diego-NCTD	9030	154		21			U	✓
12	CA	San Jose-SCCTD	9013	484				53	T, W, P	✓
13	CA	Santa Barbara-MTD	9020	77					U	
14	CA	Santa Rosa-Sonoma County	9089	56					T, P	
15	CA	Ventura Intercity Service	9164	12					I, T, P	✓
16	CT	New Britain Transit	1047	11					U	
17	CT	New Haven-CT Transit	1055	111					T	✓
18	CT	Norwalk-Wheels	1057	38					U	✓
19	CT	Waterbury-GWTD	1104		13				U	✓
20	FL	Bradenton-MCT	4026	16					P	
21	FL	Ft. Lauderdale-BCT	4029	232					U	
22	FL	Ft. Lauderdale-TCRA	4077			34			T	
23	FL	Ft. Pierce-St. Lucie COA	4097		71				P	
24	FL	Tampa-Hartline	4041	189					U	
25	FL	West Palm-CoTran	4037	154					U	
26	GA	Atlanta-MARTA	4022	783			238		T, W, P	✓
27	GA	Columbus-METRA	4024	30					T	
28	IA	Des Moines-Metro	7010	93					P	
29	IL	Chicago-RTA-Metra	5118			1,114			P	
30	IN	Evansville-METS	5043	26					T	
31	KY	Louisville-TARC	4018	306					U	
32	MA	Boston-MBTA	1003				408	173	I, P	
33	MA	Hyannis-Cape Cod-CCRTA	1105	28					T, W, P	
34	MA	Lowell-LRTA	1005	31					U	
35	MA	Worcester-WRTA	1014	52					P	
36	MD	Baltimore-Harford	3074	14					P	
37	MD	Baltimore-Maryland-MTA	3034			134			T, P	✓
38	ME	Bangor-The Bus	1096	11					U	
39	MI	Ann Arbor-AATA	5040	69					I, T, P	
40	MI	Lansing-CATA	5036	68					I	
41	MN	Minneapolis-St. Paul-MCTO	5027	894					P	✓
42	MS	Gulfport-Coast	4014	25					P	
43	NC	Charlotte-CTS	4008	170					U	
44	NJ	New Jersey Transit	2080	2,098		944			I	
45	NJ	NJ/NY-Rockland	2149	135					W	✓
46	NJ	NJ-NJTC/Hudson Transit	2126	141					P	
47	NY	Albany-CDTA	2002	227					P	
48	NY	Ithaca-TOMTRAN	2145	41					U	
49	NY	NY-Monsey New Square	2135	24					P	
50	NY	NY-MTA-Long Island Bus	2007	318					T, P	✓
51	NY	NY-MTA-Long Island RR	2100			1,187			U	✓

Source: Advanced Public Transportation Systems Deployment in the United States'; The Volpe Center, U.S. DOT; January, 1999

APTS System Deployments

Table B-7. Operational Traveler Information Systems (continued)

Index	State	Transit System	NTDB-ID	MB	Number of Vehicles DRT	CR	HR	LR	Traveler Information	Multi-modal Traveler Information
52	NY	NY-Rockland-Transport	2084	51					P	
53	NY	NY-Westchester-Liberty	2079	324					U	
54	OH	Akron-Metro	5010	138					I, T	
55	OH	Cleveland-RTA	5015	715			59	47	P	
56	OH	Dayton-RTA	5017	222					I	
57	OR	Portland-Tri-Met	0008	625					P	
58	OR	Salem-Charriots	0025	50					P	
59	PA	Scranton-Colts	3025	35					I	
60	RI	Providence-RIPTA	1001	221					U	
61	TN	Memphis-MATA	4003	194				10	P	
62	TX	Dallas-DART	6056	543		12		40	I, P	
63	TX	Houston-Metro	6008	1,202					U	
64	TX	San Angelo-Antran	6037	7					U	
65	TX	San Antonio-VIA	6011	498					P	
66	VA	Prince William-PRTC	3070	75					I, T	
67	VA	VA-VRE	3073			71			T, P	
68	WA	Bremerton-Kitsap Transit	0020	119					U	
69	WA	Richland-Ben Franklin	0018	58					U	
70	WA	Seattle-Metro	0001	1,114					T, P	✓
71	WI	Janesville-JTS	5108	23					P	
72	WI	Madison-MMT	5005	188					P	

Source: Advanced Public Transportation Systems Deployment in the United States'; The Volpe Center, U.S. DOT; January, 1999

Table B-8. Traveler Information Systems Under Implementation

Index	State	Transit System	NTDB-ID	MB	Number of Vehicles DRT	CR	HR	LR	Traveler Information	Multi-modal Traveler Information
1	AZ	Phoenix-Mesa SunRunner	9129	23					T	
2	AZ	Tucson-Sun Tran	9033	203					I, T	
3	CA	LA-Access	9157		243				P	✓
4	CA	LA-Commerce	9043	10					U	
5	CA	San Joaquin -Smart	9012	95					P	
6	CO	Denver-RTD	8006	849				17	T, W, P	
7	CT	Danbury-HART	1051	23					U	
8	FL	Orlando-LYNX	4035	205					P	
9	ID	Pocatello Urban Transit	0022	11					U	
10	IL	Champaign-Urbana-MTD	5060	94					U	
11	IL	Chicago-RTA-Pace	5113	762					P	✓
12	IL	Rock Island-Metro Link	5057	66					T, W, P	✓
13	MA	Lawrence-MVRTA	1013	45					I	
14	MA	Springfield-PVTA	1008	41					P	✓
15	MD	Maryland-Ride-On	3051	267					W, P	
16	MI	Detroit-D-DOT	5119	601					P	
17	NY	NY-MTA-NYCTA	2008	3,867					T, W, P	✓
18	NY	Port Authority-PATH	2098				342		T	
19	PA	Wilkes-Barre-(L)	3015	42					I, T	
20	TN	Knoxville-K-Trans	4002	88					P	
21	TN	Nashville-MTA	4004	140					W, P	
22	VA	Roanoke-Valley Metro	3007	38					P	
23	WA	Tacoma-Pierce Transit	0003	193					U	✓

Source: Advanced Public Transportation Systems Deployment in the United States'; The Volpe Center, U.S. DOT; January, 1999

Table B-9. Planned Traveler Information Systems

	State	Transit System		MB	DRT		HR	LR	Traveler	Multi-modal Traveler Information
1		Phoenix-Scottsdale	9131						U	
2		Contra Costa-WESTCAT	9159						U	
3		Fairfield	9092						T, W, P	
4		LA-OCTA	9036						I, T, W, P	
5		Oakland-AC Transit	9014						I, T	
6		Oakland-Wheel	9144						U	
7		Riverside-RTA	9031						I, T, W, P	✓
	CA	San Diego Transit		313					I, T, W, P	
9	CA		9016	283						✓
10		SF-SamTrans	9009						I	
11		Ventura-Thousand Oaks	9165						I	
12		Colorado Springs Transit	8005						T, P	
13		Delaware-DTC	3075						U	
14		Iowa City-CAMBUS	7019						T	✓
	IL	Chicago-RTA-CTA		1,882			1,150			✓
16		Peoria-GP Transit	5056						P	
17		Lafayette-GLPTC	5051						P	
18		Wichita-MTA	7015						U	
19		Lexington-Fayette-LexTran	4017						T, P	✓
	MA	New Bedford-SERTA		79					U	
	MA	Providence-GATRA		35					U	
	ME	Portland-METRO		24					T, W, P	
23	MN		5092	26						✓
24		Kansas City-KCATA	7005						I	
25		Great Falls-GFT	8012						U	
26		Winston-Salem-WSTA	4012						U	
27		Portsmouth-COAST	1086						I	
28		Albuquerque-Sun Tran	6019						P	✓
	NY	Poughkeepsie-LOOP		28					U	
30	OR		0007	97						
31	PA		3011	29						
32	PA		3023	14						
33	PA		2075				121			
34	PA		3026	21						
35	SC		4056	6						
36	TN		4054	10						
37	TX		6048	340						
38	TX		6014	17						
39	WA		0024	105						
40	WI		5008	535						
41	WI		5096	20						✓
42		Racine-Belle Urban System	5006						P	

Source: January, 1999

APTS System Deployments

Table B-10. Operational Electronic Fare Payment Systems

Index	State	Transit System	NTDB-ID	MB	DRT	CR	HR	LR	Automated Fare Payment	Multi-Carrier Fare Integration
				Number of Vehicles						
1	AZ	Phoenix-Mesa SunRunner	9129	23					MS, CC	✓
2	AZ	Phoenix-RPTA	9136	53					CC	✓
3	AZ	Phoenix-Scottsdale	9131	6					CC, DC	✓
4	CA	LA-Culver City	9039	30					MS	✓
5	CA	LA-Foothill Transit	9146	259					MS	✓
6	CA	LA-Montebello	9041	46					MS	✓
7	CA	LA-Norwalk	9022	22	4				MS	✓
8	CA	LA-Torrance	9010	74					SC	
9	CA	Oxnard-SCAT	9035	46					SC	✓
10	CA	San Diego-NCTD	9030			21			CC	
11	CA	San Francisco-BART	9003				668		MS, [SC]	✓
12	CA	San Joaquin-Smart	9012	95	36				MS	
13	CA	Ventura-Thousand Oaks	9165	4					SC	✓
14	CA	Ventura Intercity Service	9164	12	6				SC	✓
15	CT	New Britain Transit	1047	11					MS	✓
16	CT	New Haven-CT Transit	1055	111					MS	✓
17	CT	New Haven-NET	1095	41					MS	✓
18	DC	Washington-WMATA	3030				764		MS, [SC]	
19	FL	Ft. Lauderdale-TCRA	4077			34			CC	
20	FL	Jacksonville-JTA	4040	188					MS	
21	IL	Chicago-RTA-CTA	5066	1,882			1,150		MS	✓
22	IL	Chicago-RTA-Pace	5113	762					MS, [SC]	✓
23	IN	Evansville-METS	5043	26					MS, SC	
24	MA	Worcester-WRTA	1014	52					MS	
25	MI	Flint-MTA	5032	206					DC	
26	MN	Minneapolis-St. Paul-MCTO	5027	894					MS	✓
27	NY	NY-MTA-Long Island Bus	2007	318					MS	✓
28	NY	NY-MTA-Long Island RR	2100			1,187			MS	✓
29	NY	NY-MTA-NYCTA	2008	3,867			5,790		MS	✓
30	NY	NY-MTA-Staten Island	2099				64		MS	✓
31	NY	Port Authority-PATH	2098				342		MS	
32	NY	Rochester-RTS	2113	237					U	
33	NY	Syracuse-RTA-Centro	2018	174	17				MS	
34	PA	Philadelphia-PATCO	2075				121		U	
35	TX	Temple Transit	6075		4				DC	
36	VA	Charlottesville Transit	3036	19					U	
37	VA	VA-VRE	3073			71			CC, DC	

Source: Advanced Public Transportation Systems Deployment in the United States'; The Volpe Center, U.S. DOT; January, 1999

Table B-11. Electronic Fare Payment Systems Under Implementation

Index	State	Transit System	NTDB-ID	MB	DRT	CR	HR	LR	Automated Fare Payment	Multi-Carrier Fare Integration
				Number of Vehicles						
1	IA	Des Moines-Metro	7010	93					MS, SC	
2	MA	Springfield-PVTA	1008	41					MS	
3	MI	Lansing-CATA	5036	68					U	
4	NC	Charlotte-CTS	4008	170	48				MS, SC	
5	OK	Oklahoma City-COTPA	6017		65				MS	
6	WI	Milwaukee-Waukesha Metro	5096	20					MS	

Source: Advanced Public Transportation Systems Deployment in the United States'; The Volpe Center, U.S. DOT; January, 1999

APTS System Deployments

Table B-12. Planned Electronic Fare Payment Systems

Index	State	Transit System	NTDB-ID	Number of Vehicles MB	DRT	CR	HR	LR	Automated Fare Payment	Multi-Carrier Fare Integration
1	AL	Gadsden-Dial-A-Ride	4049		11				SC	
2	CA	Contra Costa-WESTCAT	9159	16	11				SC	✓
3	CA	Fairfield	9092	26					SC	✓
4	CA	LA-LACMTA-Metro	9154	2,413			30	69	MS, SC	✓
5	CA	LA-OCTA	9036	428	98				U	✓
6	CA	LA-Santa Monica	9008	135					MS	✓
7	CA	Oakland-AC Transit	9014	694					MS	✓
8	CA	Oakland-Vallejo Transit	9028	49					SC	
9	CA	Oakland-Wheel	9144	50	8				SC	✓
10	CA	Riverside-RTA	9031	107	36				SC	✓
11	CA	San Bernardino-OMNITRANS	9029	137					MS	✓
12	CA	San Jose-SCCTD	9013	484				53	SC, CC	
13	CA	Santa Clara - Outreach	9160		155				SC	✓
14	CA	Santa Cruz-METRO	9006	78					MS	
15	CA	Santa Rosa-City Bus	9017	21					U	✓
16	CA	SF-CalTrain	9134			93			SC	✓
17	CA	SF-Golden Gate	9016	283					SC	✓
18	CA	Tri Delta Transit	9162	26	18				SC	✓
19	CO	Colorado Springs Transit	8005	51					SC	
20	CO	Denver-RTD	8006	849				17	SC	✓
21	FL	Clearwater-Pasco Shuttle	4074	8					U	
22	FL	Ft. Lauderdale-BCT	4029	232					U	
23	FL	Orlando-LYNX	4035	205					MS	
24	FL	Pensacola-ECTS	4038	39					SC	
25	FL	Tampa-Hartline	4041	189					MS	✓
26	IA	Dubuque, IA-KeyLine	7011	18	6				SC	✓
27	IA	Five Seasons Trans	7008	40	33				MS	
28	IA	Waterloo-MET	7013	18					MS, SC	
29	ID	Boise Urban Stages	0011	37					U	
30	MA	Hyannis-Cape Cod-CCRTA	1105	28	67				MS, CC	✓
31	MI	Ann Arbor-AATA	5040	69					SC	✓
32	MN	Duluth-DTA	5025	82					U	
33	MN	St. Cloud-Metro Bus	5028	28	22				U	✓
34	NC	Greensboro-GTA	4093	25	19				SC	
35	ND	Grand Forks-City Bus	8008		11				DC	✓
36	NY	Ithaca-TOMTRAN	2145	41	16				MS	
37	NY	NY-Hauppage-Suffolk Trans	2072	164	26				MS	
38	NY	NY-MTA-Metro North RR	2078			880			CC	
39	NY	NYCDOT-Liberty	2117	86					MS	✓
40	OH	Cleveland-RTA	5015				59	47	SC	
41	OR	Eugene-LTD	0007	97					SC	
42	PA	Altoona-AMTRAN	3011	29					SC	
43	SC	Florence-PDRTA	4056	6					SC	
44	TN	Memphis-MATA	4003	194					[U]	
45	TX	Corpus Christi-The B	6051	67	40				SC	
46	TX	Fort Worth-The T	6007	154	78				SC	✓
47	WA	Bremerton-Kitsap Transit	0020	119					SC	✓
48	WA	Seattle-Everett	0005	41					SC	✓
49	WA	Seattle-Metro	0001	1,114					SC	✓

Source: Advanced Public Transportation Systems Deployment in the United States'; The Volpe Center, U.S. DOT January, 1999

Appendix C

National Transit Database Data Used in the Analysis

Transit Revenues

- Total Transit Revenue
- Transit Farebox Revenues

Transit Operating Expenses (see note)

- Vehicle Operations
- Vehicle Maintenance
- Non-Vehicle Maintenance
- General and Administrative
- Purchased Transportation

Transit Service Characteristics (see note)

- Number of Vehicles Available for Maximum Service
- Number of Vehicles Operated in Maximum Service
- Number of Route Miles

Transit Service Supplied (see note)

- Scheduled Annual Vehicle Revenue Miles
- Total Annual Vehicle Miles
- Total Annual Vehicle Revenue Miles
- Total Annual Vehicle Hours
- Total Annual Vehicle Revenue Hours

Transit Service Consumed (see note)

- Annual Unlinked Passenger Trips
- Annual Passenger Miles

Transit Performance Indicators (see note)

- Annual Vehicle Revenue Miles per Vehicle Operated in Maximum Service
- Annual Vehicle Revenue Hours per Vehicle Operated in Maximum Service
- Annual Vehicle Revenue Miles per Vehicle Revenue Hour
- Annual Operating Expenses per Vehicle Revenue Mile
- Annual Operating Expenses per Vehicle Revenue Hour
- Annual Operating Expenses per Passenger Trip
- Annual Operating Expenses per Passenger Mile
- Annual Passenger Trips per Vehicle Revenue Mile
- Annual Passenger Trips per Vehicle Revenue Hour

Note: Data within these categories were available for each transit mode (motorbus, demand responsive, commuter rail, heavy rail, and light rail).

Appendix D

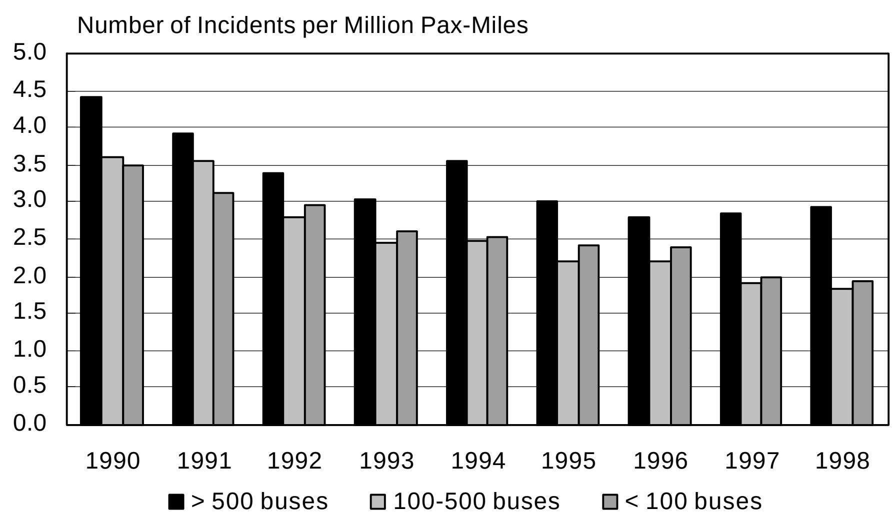
National Transit Database Safety Management Information System Data

Number of Incidents:

Definition: Collisions, personal casualties, derailments/left roadway, fires and property damage greater than $1,000 associated with transit agency revenue vehicles and all transit facilities.

Source: FTA Safety Management Information System Data (1990-1998)

Number of Incidents				
Urban Areas with Bus Fleets				
Year	> 500 buses	100-500 buses	< 100 buses	Total
1990	41,266	21,764	7,407	70,437
1991	37,403	20,116	5,934	63,453
1992	30,652	16,222	5,308	52,182
1993	26,626	14,109	4,845	45,580
1994	30,038	14,809	4,338	49,185
1995	25,599	13,102	4,079	42,780
1996	23,060	13,437	3,959	40,456
1997	25,833	11,423	3,268	40,524
1998	26,677	11,308	3,631	41,616



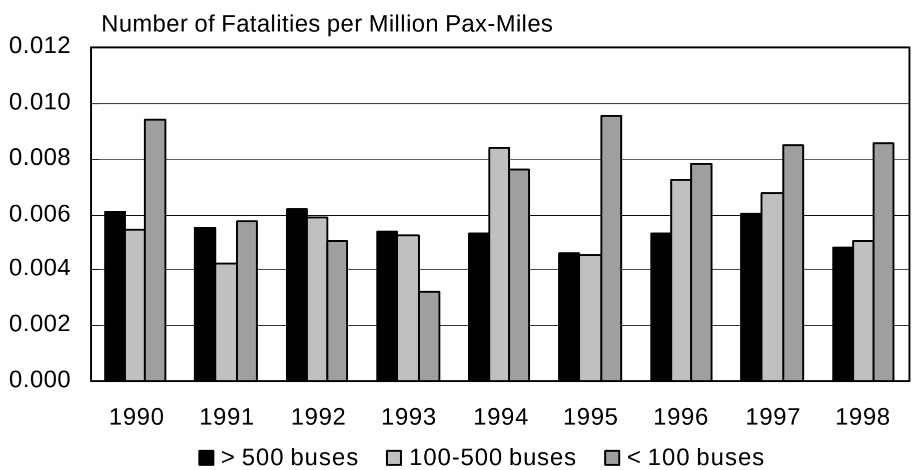
National Transit Database Safety Management Information System Data

Number of Fatalities:

Definition: A transit-caused death confirmed within 30 days of a transit incident.

Source: FTA Safety Management Information System Data (1990-1998)

Number of Fatalities				
Urban Areas with Bus Fleets				
Year	> 500 buses	100-500 buses	< 100 buses	Total
1990	57	33	20	110
1991	53	24	11	88
1992	56	34	9	99
1993	47	30	6	83
1994	45	50	13	108
1995	39	27	16	82
1996	44	44	13	101
1997	55	40	14	109
1998	44	31	24	99



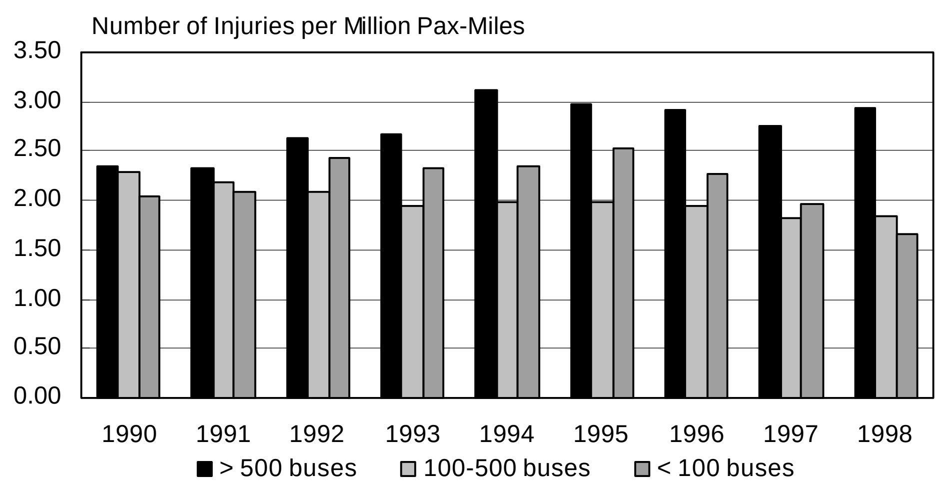
National Transit Database Safety Management Information System Data

Number of Injuries:

Definition: Any physical damage or harm to a person requiring medical treatment, or any physical damage or harm to a person reported at the time or place of occurrence. For employees, an injury includes incidents resulting in time lost from duty or any definition consistent with a transit agency's current employee injury reporting practice.

Source: FTA Safety Management Information System Data (1990-1998)

Number of Injuries				
Urban Areas with Bus Fleets				
Year	> 500 buses	100-500 buses	< 100 buses	Total
1990	21,891	13,780	4,335	40,006
1991	22,301	12,366	3,952	38,619
1992	23,654	12,090	4,346	40,090
1993	23,393	11,153	4,327	38,873
1994	26,365	11,798	4,032	42,195
1995	25,284	11,756	4,257	41,297
1996	24,111	11,843	3,755	39,709
1997	25,058	10,882	3,241	39,181
1998	26,671	11,255	3,109	41,035



National Transit Database Safety Management Information System Data

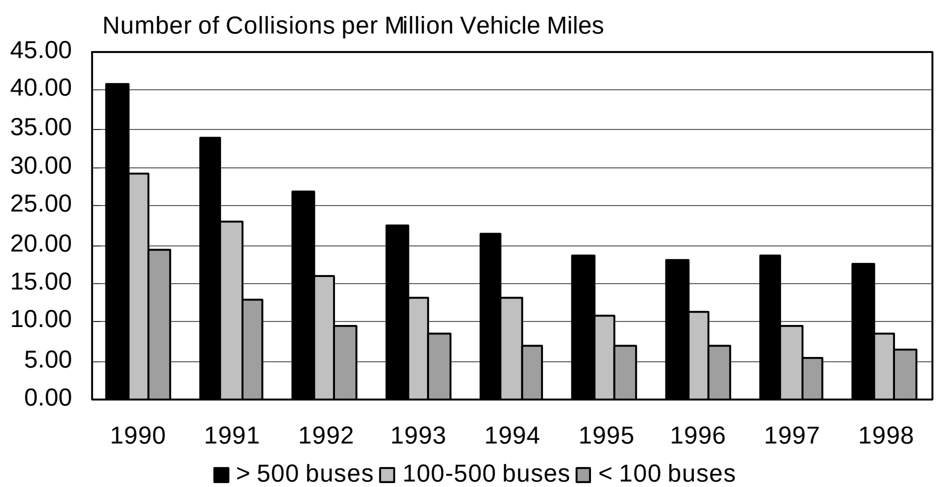
Number of Collisions:

Definition:

With Vehicle	An incident in which a transit vehicle strikes or is struck by another vehicle. Reports are made if accident results in death, injury, or property damage over $1,000.
With Object	An incident in which a transit vehicle strikes an obstacle other than a vehicle or person. Reports are made if accident results in death, injury, or property damage over $1,000.
With People	An incident in which a transit vehicle strikes a person. Except where specifically indicated, collisions with people do not include suicide attempts. Reports are made if the incident results in death, injury, or property damage over $1,000.

Source: FTA Safety Management Information System Data (1990-1998)

Number of Collisions				
Urban Areas with Bus Fleets				
Year	> 500 buses	100-500 buses	< 100 buses	Total
1990	32,057	17,282	5,737	55,076
1991	27,608	13,159	3,583	44,350
1992	21,994	9,576	2,634	34,204
1993	18,177	7,904	2,410	28,491
1994	17,450	8,324	1,851	27,625
1995	15,035	6,866	1,832	23,733
1996	14,091	7,366	1,848	23,305
1997	15,619	5,924	1,376	22,919
1998	14,870	5,524	1,826	22,220



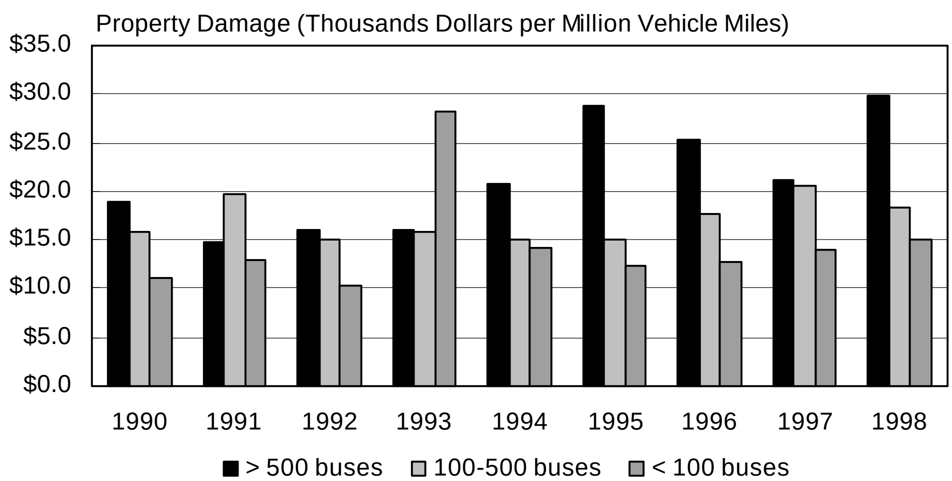
National Transit Database Safety Management Information System Data

Property Damage (Thousands of Dollars):

Definition: The dollar amount required to repair or replace transit property damaged during an incident.

Source: FTA Safety Management Information System Data (1990-1998)

Property Damage (in Thousands of Dollars)				
Urban Areas with Bus Fleets				
Year	> 500 buses	100-500 buses	< 100 buses	Total
1990	$14,760	$9,344	$3,264	$27,368
1991	$12,051	$11,239	$3,543	$26,833
1992	$13,106	$8,901	$2,808	$24,814
1993	$13,091	$9,440	$7,972	$30,503
1994	$16,755	$9,491	$3,748	$29,994
1995	$23,305	$9,474	$3,241	$36,020
1996	$19,791	$11,476	$3,355	$34,622
1997	$17,801	$12,795	$3,568	$34,165
1998	$25,189	$11,930	$4,237	$41,355



References

1. Federal Transit Administration, 1997 National Transit Database and 1997 National Transit Summaries and Trends, U. S. Department of Transportation; 1997.

2. The Volpe Center, Advanced Public Transportation Systems: The State of the Art - Update '96; U.S. Department of Transportation; January 1996.

3. The Volpe Center, Advanced Public Transportation Systems: The State of the Art - Update '98; U.S. Department of Transportation; January 1998.

4. The Volpe Center, Advanced Public Transportation Systems Deployment in the United States; U.S. Department of Transportation; August 1996.

5. The Volpe Center, Advanced Public Transportation Systems Deployment in the United States; U.S. Department of Transportation; January 1999.

6. U.S. Department of Transportation's Intelligent Transportation System Joint program Office (ITS-JPO), "Metropolitan Intelligent Transportation Systems Infrastructure Deployment Tracking Database"; [http://itsdeployment.ed.ornl.gov/.

7. Transportation Research Board, TCRP Synthesis 24 AVL Systems for Bus Transit, Transportation Cooperative Research Program, National Academy Press, Washington, D.C.; 1997.

8. Federal Transit Administration, "Transit-ITS Impacts Matrix," http://idf.mitretek.org/its/aptsmatrix.nsf; U.S. Department of Transportation.

9. Federal Transit Administration, Advanced Public Transportation Systems Benefits, U.S. Department of Transportation; March 1996.

10. Federal Highway Administration, Intelligent Transportation Systems – Real World Benefits; ITS Joint Program Office, U.S. Department of Transportation; January 1998.

11. *Mass Transit*, "Vehicle Location/Driver Communication Technologies Combine to Increase Efficiency and Reduce Costs"; November/December 1992.

12. Federal Highway Administration, Intelligent Transportation Systems Benefits:1999 Update, ITS Joint Program Office, U.S. Department of Transportation; May 1999.

13. ITS America, ITS Technologies in Public Transit: Deployments and Benefits; November 1995.

14. The Volpe Center, Advanced Public Transportation Systems: The State of the Art - Update 2000; U.S. Department of Transportation; Draft document - undated.

15. National Urban Transit Institute, Economic and Policy Considerations of Advanced Public Transportation Systems (APTS) – Assessing the Economic Feasibility of APTS; Center for Urban Transportation Research, University of South Florida; October 1994.

16. Stone, J., Ph.D., "Winston-Salem Mobility Management: An Evaluation of Computer-Aided Dispatch and Scheduling;" Paper presented at Transportation Research Board 1996 Annual Meeting, Department of Civil Engineering, North Carolina State University; August 1995.

17. Stone, J. and Nalevanko, A, Small Urban and Rural Advanced Public Transportation Systems; Department of Civil Engineering, North Carolina State University; February 1999.

18. Transportation Research Board, TCRP Report 32 Multipurpose Transit Payment Media, Transportation Cooperative Research Program; National Academy Press, Washington, D.C.; 1998.

19. Schwenk, J, Bus Fare Payment with Credit Cards in Phoenix - Case Study Report; The Volpe Center; October 1995.

20. The Volpe Center, Smart Cards for Transit: Multi-Use Remotely Interrogated Stored-Data Cards for Fare and Toll Payment, Final Report; U.S. Department of Transportation; April 1995.

21. *Mass Transit*, "Time to Get Smart;" November/December 1995.

22. Multisystems Inc., Stored Value Fare Card Pricing Survey and Ridership/Revenue Model, Final Report for the Chicago Transit Authority; December 1995.

23. *Mass Transit*, "A Joint Effort: Multi-Operator Fare Integration"; October 1994.

24. Fleishman, D et al, Transit Fare Policies, Structures, and Technologies, Final report for the Transportation Cooperative Research Program; Transportation Research Board, National Academy Press, Washington, D.C.; May 1996.

25. King County Metropolitan Services and the IBI Group, Central Puget Sound Regional Fare and Technology Coordination Feasibility Study; January 1996.

26. Benton International, TransLink Program for the Metropolitan Transportation Commission; December 1995.

27. Clayton, C., "Travlink: An Intelligent Commute in Minneapolis"; Minnesota DOT; article submitted for publication in ITE Journal; undated.

28. Federal Transit Administration, "Transit Intelligent Vehicle Initiative - Fact Sheet," U. S. Department of Transportation; June 2000.

29. Federal Transit Administration, "Intelligent Vehicle Initiative website": http://www.fta.dot.gov/research/safe/ivi/ivi.htm .

30. Volpe National Transportation Systems Center and TecMasters, Inc., Intelligent Vehicle Initiative Needs Assessment; Federal Transit Administration Report: FTA-TRI-11-99-33; November 1999.

31. Federal Transit Administration, "Bus Rapid Transit Program website": http://www.fta.dot.gov/research/fleet/brt/brt.htm.

32. Ann Arbor Transportation Authority and Veridian ERIM International, Inc., Performance Specifications for a Rear Impact Collision Warning System; Project Proposal submitted to the Federal Transit Administration; undated.

33. Metrz, Christopher, McNeil, Sue, and Thorpe, Charles; "Side Collision Warning Systems for Transit Buses;" Robotics Institute, Department of Civil and Environmental Engineering, Carnegie Mellon University; Paper presented at the 2000 Intelligent Vehicles Conference; October 4-5, 2000.

34. McNeil, Sue, Thorpe, Charles, and Metrz, Christopher, "A New Focus for Side Collision Warning Systems for Transit Buses;" Robotics Institute, Department of Civil and Environmental Engineering, Carnegie Mellon University; Paper prepared for the Intelligent Transportation Society of America's Tenth Annual Meeting and Exposition; May 2000.

35. Federal Transit Administration, "Transit Intelligent Vehicle Initiative Newsletter," June 2000.

36. Mitretek Systems, Estimating the Potential Safety Benefits of Intelligent Transportation Systems; Working Paper prepared for the Intelligent Transportation Systems Joint Program Office; November 1998.

37. U.S. Department of Transportation, ITS Joint Program Office; "Motor Vehicle Crashes – Data Analysis and IVI Program Emphasis"; November 1999.

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